Vol. 12, No. 5 September-October, 1956

LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

In This Issue

Lubrication in the Presence of Nuclear Radiation
by J. G. Carroll & R. O. Bolt 305

Current Research in the Bacteriology of Soluble Oil Emulsions
by H. Pivnick, L. R. Sabina, R. Samuel-Maharajah & C. K. Fotopoulos 310

Capillary Viscometry of Lubricating Grease
by L. C. Brunstrum & R. H. Leet 316

Place for Emulsions as Fire-Resistant Power Transmission Fluids, The
by G. T. Coker & C. E. Francis 323

Effect of Oxygen Concentration in Atmosphere on Oil Lubrication of High-Temperature Ball Bearings
by Z. N. Nemeth & W. J. Anderson 327

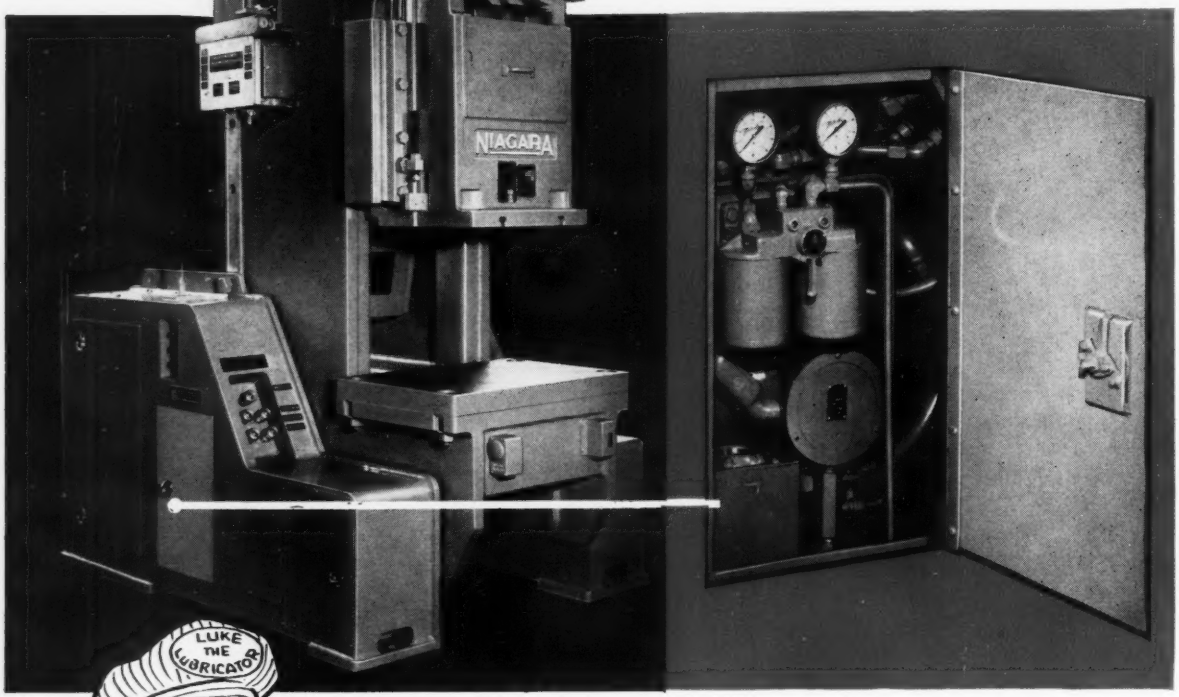
Organization of a Plant Lubrication Program — II
by O. J. Seidl 331

Advertisers' Index 352
ASLE Directory 301
ASLE News Notebook 295
Coming Events 326
Current Literature 322
Editorial: "Atoms, Automation, and ASLE," by E. R. Booser 291
Engineering Societies Personnel Service, Inc. 351
Lube Lines, by A. F. Brewer 303
Lubrication Abstracts, compiled by Henry Brutcher 315
Lubrication in the News 342
New Products 299
Patent Abstracts, compiled by Ann Burchick 347
Personals 293
Section News 326
The Sight Glass 349

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

MASTERFUL ENGINEERING . . . . . Trabon Meterflo

AUTOMATIC LUBRICATION ON NIAGARA INCLINABLE PRESSES



TRABON "METERFLO" systems automatically circulate clean, filtered oil under pressure to all bearings; air counter-balance; and slide gibs, on the new Niagara front-to-back crankshaft open back inclinable presses illustrated.

TRABON'S exclusive warning devices react immediately to the inability of any bearing or line to receive oil. The positive progressive action of the piston type distributors is stopped, causing pressure switch to stop the press.

Another example of the application of the World's Finest Automatic Lubrication for Automation or Single Purpose equipment.

Trabon ENGINEERING CORPORATION

1814 E. 40th STREET • CLEVELAND 3, OHIO

Oil and Grease Systems

ASLE MEMBERSHIP CLASSIFICATIONS

Membership in the American Society of Lubrication Engineers is in several grades as defined below. Assignment to grade is made by the Admissions Committee or Board of Directors on the basis of information submitted or supplied by references.

Members: Members shall be persons not less than 24 years of age who: (1) are engaged in research and instruction at technical schools, universities, and various publicly and privately supported institutions in the field of lubrication; or (2) have occupied recognized positions as lubrication engineers for a period of three or more (not necessarily consecutive) years prior to date of admission, involving the responsibilty for or supervision of the development, selection, field use and application of lubricants as differentiated from other activities; or (3) are indirectly concerned with the field of lubrication, but possessing other qualifications of experience, knowledge, and accomplishment, and have manifested a particular interest in the purposes and welfare of the Society to the extent that their membership would be a valuable contribution to the successful functioning of its activities. Fee $15.00.

Associate Members: Associate Members shall be persons less than 24 years of age, and those who do not completely fulfill the membership requirements for Members. Fee $7.50.

Sectional Sustaining Members: Sectional Sustaining Members are such persons or organizations as may be interested in and desire to contribute to the support of the purposes and activities of a local Section of the Society. Fee $25.00.

Industrial Members: Industrial Members are such persons or organizations as may be interested in and desire to contribute to supporting the purposes and activities of the Society. Fee $150.00.

For application blanks or further information, write:

ASLE
84 E. Randolph St.
Chicago 1, Ill.

LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

Volume 12, No. 5 September-October, 1956

Table Of Contents

Lubrication in the Presence of Nuclear Radiation
by J. G. Carroll & R. O. Bolt 305

Current Research in the Bacteriology of Soluble Oil Emulsions
by H. Pivnick, L. R. Sabina, R. Samuel-Maharajah & C. K. Fotopoulos.... 310

Capillary Viscometry of Lubricating Grease
by L. C. Brunstrum & R. H. Leet 316

Place for Emulsions as Fire-Resistant Power Transmission Fluids, The
by G. T. Coker & C. E. Francis 323

Effect of Oxygen Concentration in Atmosphere on Oil Lubrication of High-Temperature Ball Bearings
by Z. N. Nemeth & W. J. Anderson 327

Organization of a Plant Lubrication Program — II
by O. J. Seidl 331

Advertisers' Index 352
ASLE Directory 301
ASLE News Notebook 295
Coming Events 326
Current Literature 322
Editorial: "Atoms, Automation, and ASLE," by E. R. Booser 291
Engineering Societies Personnel Service, Inc. 351
Lube Lines, by A. F. Brewer 303
Lubrication Abstracts, compiled by Henry Brutcher 315
Lubrication in the News 342
New Products 299
Patent Abstracts, compiled by Ann Burchick 347
Personals 293
Section News 326
The Sight Glass 349

LUBRICATION ENGINEERING is published bi-monthly by the American Society of Lubrication Engineers, 84 E. Randolph St., Chicago 1, Illinois (Phone, DEarborn 2-1298). Current single copies 75c, annual subscription rate $4.00 in the United States and Canada, $4.50 in all other countries.

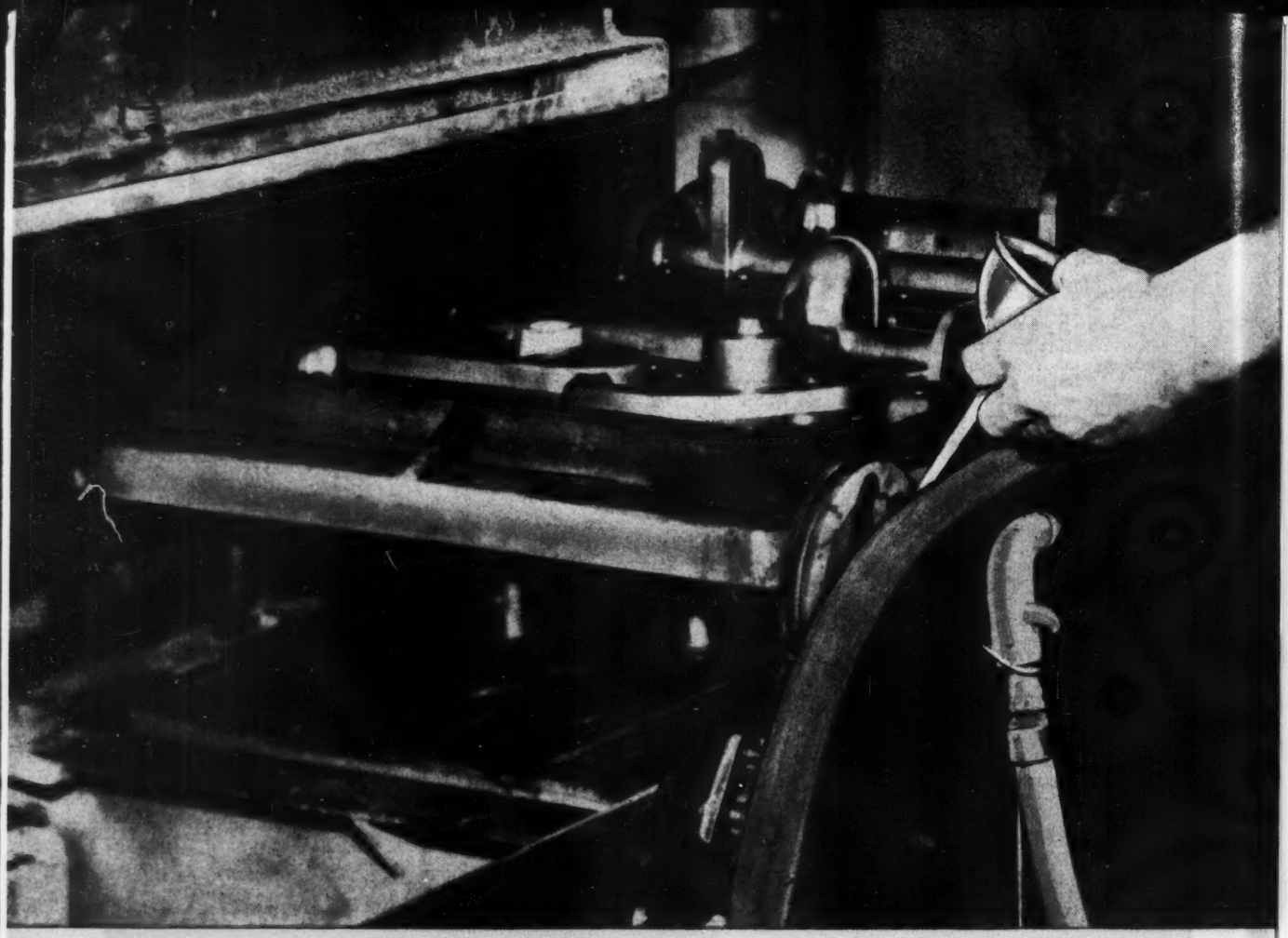
Copyright 1956 by the American Society of Lubrication Engineers. ASLE will not be responsible for statements or opinions advanced in its meetings or printed in its publications.

Editor ..... R. K. Gould, The Texas Co., Beacon, N. Y.
Associate Editor ..... C. R. Kluge, ASLE National Office, 84 E. Randolph St., Chicago 1, Ill.
Consulting Editor ..... A. F. Brewer, Consultant
Advertising and Business Manager ..... W. P. Youngclaus, Jr., ASLE National Office
ASLE Publications Manager ..... R. D. McCormick, ASLE National Office

Editorial Committee

R. K. Gould (Chairman), The Texas Co. ..... R. D. McCormick, ASLE National Office
F. R. Archibald, Arthur D. Little, Inc. ..... J. J. O'Connor, McGraw-Hill Publishing Co.
J. Faust, L. Sonneborn & Sons, Inc. ..... D. W. Sawyer, Aluminum Co. of America
R. H. Josephson, Cleveland Graphite Bronze Co. ..... S. K. Talley, Shell Development Co.
C. R. Lewis, Standard Oil Co. (Ind.) ..... A. C. West, California Research Corp.

Engravings by **Graphic Photo-Engravers** (Chicago), and **The Kentucky Engraving Co.** (Lexington)
Printed by **Publishers Printing Co., Inc.**, 112-116 E. Chestnut St., Louisville 2, Ky.
(Second class mail privileges authorized at Chicago, Ill.)



'dag' dispersions . . . *a touch does so much!*

'Oildag' vital to continuous molding-machine operation

Production Pattern & Foundry Company of Chicopee, Mass. runs its five shell-molding machines 24 hours a day to keep up with casting-floor demand for molds. To stand up under this tough service, the machines must be properly maintained.

Maintenance personnel at Production Pattern & Foundry have found that lubrication instructions of the machine's manufacturer have paid off handsomely. Shell Process Co., which makes these shell-molding machines, recommends **'Oildag'** — colloidal graphite in petroleum oil — diluted with five parts of No. 10 oil for the lubrication of critical wear points: the axle bearings of the drive mechanism, and hitch-pivots and link pins of the roller chain. Since the roller chain is subjected to 900° F temperatures within the shell-baking oven, conventional lubricants would be useless . . . would decompose and carbonize. Proof of the effectiveness of colloidal graphite for this heavy-duty high-temperature lubrication job is the fact that the machines have operated without breakdown for more than six years!

Dispersions of colloidal graphite are extremely valuable elsewhere in the foundry too: as long-lasting lubricants for moving parts of casting machines and other foundry mechanisms; as heat-resistant ladle coatings, and effective mold coatings for better parting and controlled cooling. You can learn more about the use of **'dag'** dispersions in metal-casting operations through Acheson's Bulletin 425. Write for your free copy today.

100th Anniversary

1891—SILICON CARBIDE
1895—SYNTHETIC GRAPHITE
1906—COLLOIDAL GRAPHITE

ACHESON COLLOIDS COMPANY
PORT HURON, MICHIGAN
. . . also Acheson Colloids Ltd., London, England

ACHESON COLLOIDAL DISPERSIONS:
Graphite • Molybdenum Disulfide • Zinc Oxide • Mica and other solids

'dag' and 'Oildag' are registered trademarks of Acheson Industries, Inc.

ACHESON COLLOIDS COMPANY
Port Huron, Michigan, Dept. G-9

Yes, I want your free bulletin describing 'dag' Dispersions for High-Temperature Lubrication.

Name_____
Title_____
Company_____
Address_____
City_____ Zone____ State_____

LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

Volume 12, No. 5
September-October 1956

Atoms, Automation, and ASLE

How will you be living — say in 1976? What new appliances will you have in your home? How will you be traveling? How will your factory be run? What role will we as lubrication engineers be playing in these advances?

Any speculation you make will lead you to one conclusion: We are in the early stages of a new era. Faster jet-propelled travel will be an important part of it. Shorter working hours and increased production will be key phenomena. We are already seeing new ways of home living, faster communications . . . all centered around new concepts in harnessing and using energy. We are shifting from our present machine age into something new . . . an age featuring atomic energy and automatic machines.

Development of new sources of power will play a major role in this revolution. Petroleum and natural gas have experienced tremendous growth in the last half century. Electric power has been doubling every eight to ten years. Energy directly from the sun is being explored. But the big new source of POWER is from the ATOM; we look to atomic energy to free us from any future bonds we may have otherwise encountered in our energy supply.

The other big part of our new era is the development of new ways of using power to do our work. Overloaded electrical outlets in our homes attest to our expanding daily use of power for washing, cleaning, lighting and play. The 8,000,000 new cars in the past year, 100,000,000 new electric motors, new orders for jet airliners . . . all are evidence of its wider application.

Automation in our mills and factories represents the complete harnessing of power to earn our living. We already find automation in our petroleum refineries, in automobile plants, in food processing, in our telephone systems, and in manufacturing appliances.

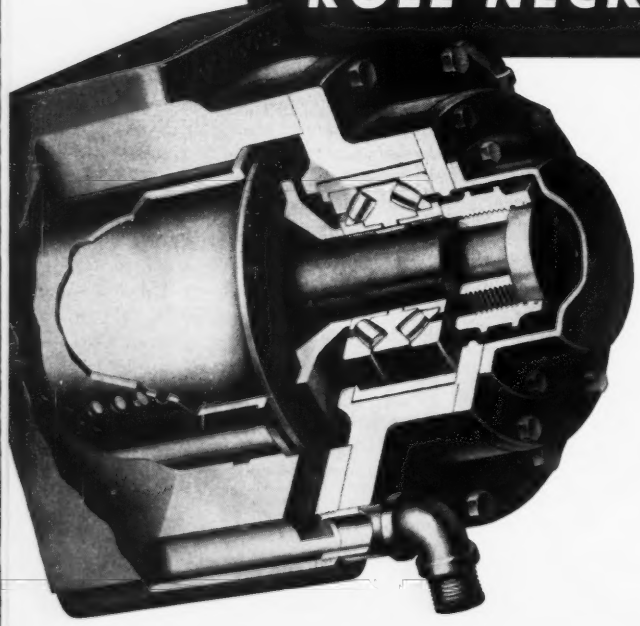
And how will lubrication contribute in our new era? Basically, it will be one of the few common denominators. Power production, power utilization . . . nearly everything developed in our new era will involve mechanical motion . . . *and will require lubrication.* Centralized lubrication systems will require further development for application on an ever-expanding scale. Higher bearing speeds and greater gear loads will be universally encountered. Synthetic lubricants will be pushed to their limit to keep up with the race of jet planes toward the thermal barrier. New concepts will be needed for lubricating atomic power reactors with water and liquid metals.

The challenge is clear. Through our Society we must develop the science and practice of lubrication and publicize its importance to designers, to industry, and to our schools. The Society is yours. You and I working together can make ASLE work for us as we face the lubrication problems in this new era of atoms and automation.

E. R. BOOSER, President
American Society of Lubrication Engineers

Morgan Quality in Action

MORGOIL
ROLL NECK BEARINGS



These 26″-90 MORGOIL Bearings are operating in a 10½″ & 30″ x 30″ single stand four high reversing cold mill at Lombarde Falck in Milan, Italy. Hot mills or cold mills, ferrous or nonferrous, at home or abroad, MORGOILS give the best roll neck bearing performance at the lowest cost.

MORGAN CONSTRUCTION CO.
WORCESTER, MASSACHUSETTS

ROLLING MILLS MORGOIL BEARINGS GAS PRODUCERS
WIRE MILLS EJECTORS REGENERATIVE FURNACE CONTROL

MB-85

MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER

MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER MORGAN WORCESTER

Personals

IN MEMORIUM: George L. Sumner (ASLE Pittsburgh Section, former Director and fourth President of ASLE). George Lewis Sumner was born June 20, 1888. He graduated from the Pennsylvania State College in 1914, majoring in Chemistry. He was employed by the Illinois Steel Company at Gary, Indiana, as a Chemist and later worked for the National Tube Company of McKeesport, Pennsylvania. In 1917 he was employed by the Westinghouse Electric & Manufacturing Company as a Chemical Engineer in the research division. His work dealt with insulating oil development and lubricating problems. He was active in various ASTM committees and Committee Z-11 of ASA. During the war George Sumner was Liaison Engineer on plant lubrication, cutting fluids, and finishes, to the three Naval Ordnance plants operated by Westinghouse. Before retirement from Westinghouse in July of 1953, he held the position of Application Engineer-in-Charge. In an editorial for the August 1948 issue of **Lubrication Engineering**, Mr. Sumner wrote: "Some of us do not appreciate the full breadth of the field of lubrication as it tends to become obscured in the ramifications of the many other fields which it serves." As an ASLE President, George Sumner fought for professional recognition and fundamental research into the lubrication design factors so that oil flow and bearing application might be on an engineering basis rather than by trial and error. With the death of George Sumner, July 30, 1956, ASLE lost a dedicated leader and firm supporter of Society activities.

J. L. Finkelmann (ASLE Detroit Section, and Secretary of ASLE) has joined the Cycleweld Division of the Chrysler Corporation, 5437 W. Jefferson, Trenton, Michigan, in charge of lubricant development and production. Cycleweld Division produces special lubricants and metalworking fluids for the corporation.

C. F. Kettleborough, Senior Lecturer at the University of Melbourne, Victoria, Australia, has joined the Westinghouse Research Laboratories, Pittsburgh, as a Research Engineer in the Mechanics Department.

C. N. Rill (ASLE Cleveland Section), formerly with The Franklin Oil & Gas Co., has been appointed Director of Research for The Murphy-Phoenix Co., Division of The Phoenix Oil Co., Cleveland, Ohio.

E. F. Houghton & Co. has announced the transfer of **B. B. Flick** (ASLE Cleveland Section), former Lubrication Engineer for the company's Detroit Division, to its Pittsburgh Steel Mill Division, Pittsburgh, Pa., in charge of Sales & Service.

H. H. Platek has been appointed Advertising Manager of The Cleveland Worm & Gear Co. and its affiliate, The Farval Corp., both in Cleveland, Ohio.

W. H. Millett (ASLE New York Section) has been appointed Sales Manager, and **M. A. Bigelow, Jr.,** has been appointed Ass't. Sales Manager, Ucon Products, for Carbide & Carbon Chemicals Co., a Division of Union Carbide & Carbon Corp., N. Y. C.

The promotions of **F. A. Stockwell** to the position of Assistant to the President, and of **C. A. Stutzman** to Manager, Lubricating Equipment, have been announced by The Aro Equipment Corp., Bryan, Ohio.

C. M. Larson (ASLE New York Section, and a former Director of ASLE), after 37 years with Sinclair Refining Co., has retired to enter private practice as a Consulting Engineer. Mr. Larson is

(Continued on p. 337)

J. L. Finkelmann

C. M. Larson

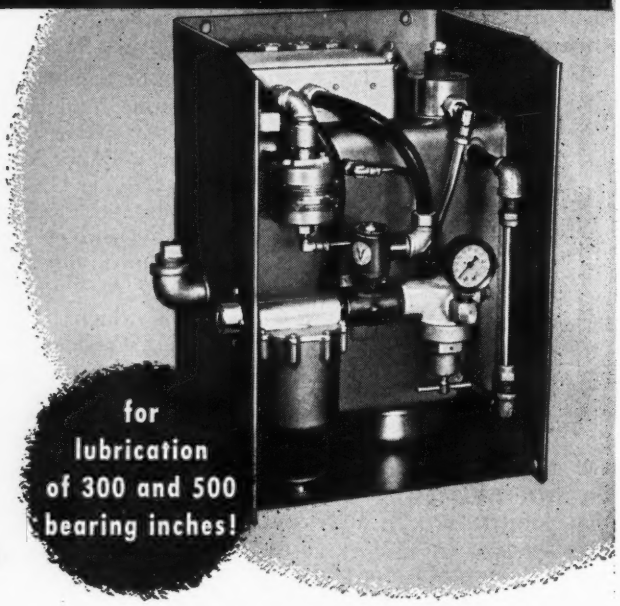
W. H. Millett

C. N. Rill

Now! Design Automatic Lubrication into your largest machines!

2 new ALEMITE OIL-MIST

AUTOMATIC LUBRICATION MODELS



Greater capacity . . . greater coverage . . . greater savings! Now the largest machines can have moneysaving, timesaving Alemite Oil-Mist Automatic Lubrication! These two new models offer greater capacity for lubricating up to 300 and 500 bearing inches! They are the same type of famous Alemite Oil-Mist systems already proved on countless machines in all types of industry.

Alemite Oil-Mist Lubricators atomize oil into mist and distribute it through tubing to all types of lubricated mechanisms—anti-friction and plain bearings, gears, slides, ways, chains, cams, and rollers. Amazingly simple, continuous and fully automatic . . . Alemite Oil-Mist eliminates the waste and uncertainties of the "human element" in lubrication.

Design more efficient, more economical, foolproof automatic lubrication into your machines. Mail coupon below for full details!

8 Advantages of the ALEMITE OIL-MIST System

1. Continuous Lubrication—Constantly deposits fresh, clean film of oil on all surfaces of all bearings in the system.

2. Fully Automatic Lubrication—Can start and stop with operation of machine switch.

3. Elimination of Guesswork—No bearing can be overlooked, nor overlubricated! Every bearing picks up only as much Oil-Mist as it needs. Eliminates waste.

4. Reduction of Bearing Temperatures—Acts as bearing coolant, can lower bearing temperatures as much as 20° F.

5. Reduction of Types of Oil—Reduces number of oils that must be stocked, handled, and applied.

6. Elimination of Downtime—All bearings in the system are constantly lubricated while machines continue to operate. Production goes up!

7. Extension of Bearing Life—Multiplies bearing life many times. Life of grinding machine bearings has extended from 400 to 7,000 hours!

8. Less Oil Consumption—about 1/10 the amount consumed by any other lubrication method!

Alemite Oil-Mist Lubricates ALL Types of Mechanisms

Anti-friction Bearings | Plain Bearings | Chain | Gear | Gear Cases

ALEMITE
OIL-MIST

STEWART SW WARNER

A Product of STEWART-WARNER CORPORATION

Alemite Division of Stewart-Warner, Dept. P-106
1850 Diversey Parkway, Chicago 14, Illinois

☐ Please send me a FREE copy of your new and complete Alemite Oil-Mist catalog.

☐ Please have your Alemite Lubrication Representative arrange a no-obligation demonstration.

My Name _____

Title _____

Company _____

Street _____

City _____ State _____

ASLE News Notebook

Executive Reports

Area representatives have been appointed by the regional vice presidents for the Midwestern and Central regions. Mr. A. H. Turner of the Standard Oil Co., Cleveland will cover the Cleveland-Youngstown Sections; Mr. H. W. Irion, National Refining Co., of Columbus, the Columbus Section; and Mr. G. H. Leffel of the D. A. Stuart Oil Co., Springfield will assist the vice president with the Dayton and Cincinnati Sections. Representatives for the Detroit-Saginaw Valley and Louisville-Kingsport Sections have not been appointed. To assist in the Midwestern region, R. O. Erickson of the Shell Oil Co., Minneapolis, will represent the Twin Cities-Duluth-Des Moines Sections; Mr. F. A. Rudolph, of the Sun Oil Co., Dallas, will represent the Houston Section and other Texas Sections as they are formed; and Mr. C. J. Smith, of the Cities Service Oil Co., Kansas City, to represent the Kansas City-St. Louis Sections. The area representative for the Indianapolis-Ft. Wayne Sections has not been announced. Area representatives for the Sections within the Eastern, Western, and Canadian Regions will be announced as appointed. Consult the ASLE Directory for the complete mailing addresses of the area representatives.

Section officers will be contacted by the area representative to provide help in the formulation of future programs, joint meetings, education courses, and to promote membership. The area representative is the personal representative of the regional vice-president and provides the Section with the necessary liaison and coordination for optimum growth.

Some of the regional activities which have been reported include the formation of two new Sections: Hudson-Mohawk (See Notebook and Section Activities for July-Aug.) and Duluth-Iron Range; the formation of a Section in Columbus, Ohio; and the planning of Sections for Dallas-Ft. Worth, Des Moines-Newton-Cedar Rapids, and Davenport-Rock Island-Bettendorf. Education courses have been arranged by the Chicago, Kingsport, and Baltimore Sections, and courses have been planned for the Dayton and Boston Sections.

Committee Activities

The ASLE Technical Committee on Properties of Lubricants under the chairmanship of C. W. Nichols, Jr., has announced the appointment of A. W. Lindert as chairman of the subcommittee on Papers; K. P Powers, chairman of the subcommittee on information; C. A. Bailey, chairman of the subcommittee on research; and M. L. Langworthy, chairman of the subcommittee on the Lubrication Engineering Handbook. A meeting of the committee has been tentatively scheduled for October 9, during the Lubrication Conference at Atlantic City. During the meeting the committee will discuss participation in the 1957 Annual Meeting at Detroit, the viscosity classification proposed by the ASTM, review the activities of the subcommittees, and appoint chairmen for the sessions to be sponsored by the

Welcome Duluth-Iron Range Section

Officers and guests present at the indoctrination of the Duluth-Iron Range Section included: R. O. Erickson, area representative and past chairman, Twin Cities Section; E. W. Brennan, guest speaker; Dr. A. B. Wilder, Midwestern Vice-President; B. T. Harding, National Membership and Admissions Committee Chairman; (back row) C. D. Johnson, Section Secretary; Robert Rutka, Vice-Chairman; R. D. Keech, Section Chairman; and Walter Kiriluk, Section Treasurer.

HE KEEPS THEM ROLLING—
THE MAN FROM ATLANTIC

The Atlantic specialist in industrial lubrication is a highly skilled expert. He's spent years in the study of every heavy lubricating and cutting-oil problem . . . and he's backed by other Atlantic specialists in lubrication research, production, quality control and marketing.

Atlantic's experience since 1870 has made us familiar with *your* lubricating needs. We've developed the products necessary to do any lubrication job perfectly . . . at the lowest cost . . . for every wheel that turns in industry.

Your company can benefit from our extensive experience and services. For further information on Atlantic's family of products for industrial lubrication and metal processing, write or wire Dept. L-10 The Atlantic Refining Company, at the nearest office listed below.

ATLANTIC

LUBRICANTS · WAXES
PROCESS PRODUCTS

PHILADELPHIA, PA.
260 South Broad St.

PROVIDENCE, R. I.
430 Hospital Trust Bldg.

CHARLOTTE, N. C.
1112 South Boulevard

SYRACUSE, N. Y.
Salina and Genesee Sts.

READING, PA.
First and Penn Aves.

PITTSBURGH, PA.
Chamber of Commerce Bldg.

Atlantic Refining Company of Brazil
Edificio Castello
151 Avenida Nilo Pecanha
Rio de Janeiro, Brazil

Porto Rico Oil Company, Inc.
Box 4832, San Juan, Puerto Rico

Properties of Lubricants Committee at the annual meeting. Location and time of meeting will be posted on the bulletin board in the Chalfonte-Haddon Hall at the time of registration for the conference.

Membership in the Lubrication Fundamentals, D. Godfrey, Chairman, now totals 23.

The Annual Meeting Program Committee has tentatively scheduled a meeting during the joint conference at Atlantic City on October 9. Details will be posted on the bulletin board of the Chalfonte-Haddon Hall at the time of registration.

A meeting of the Technical Advisory Board has been scheduled for 2 P.M., October 9 at the Chalfonte-Haddon Hall. Meeting room will be posted at the hotel bulletin board and the registration desk.

Dr. B. G. Rightmire, Massachusetts Institute of Technology, has been reappointed chairman of the ASLE Education Committee and Mr. R. Q. Sharpe has been appointed chairman of the Hydraulics & Hydraulic Machinery Committee.

Section Activities

Duluth-Iron Range Becomes ASLE Section

Approximately 50 members and guests were present to witness the indoctrination of the newest ASLE Section, at Duluth, Minnesota. Officially named the Duluth-Iron Range Section, the new Section is number 31 in the growing list of ASLE Sections to receive their charter. Officers for the new Section include: R. D. Keech, Chairman; R. Rutka, Vice-Chairman; C. D. Johnson, Secretary; and W. Kiriluk, Treasurer. Mr. E. W. Brennan of the Pure Oil Co., and member of the Chicago Section, spoke on "Hydraulic Fluids." Officers and distinguished guests present are shown in the accompanying photograph.

Kingsport Section Holds Education Course

A Lubrication Engineering Course was sponsored jointly by the Kingsport Section and the Mechanical Engineering Department of the University of Tennessee, September 26-27 at the Student Center of the University, Knoxville, Tennessee. Eight sessions were scheduled during the 2-day session and included, "Fundamentals of Friction and Lubrication," "Properties of Lubricants," "Gear Lubrication," "Bearings and Lubrication," "Hydraulics," "Planning a Lubrication Program," "Training Lubrication Personnel," and a panel discussion of lubrication problems. Further reports on the course will be published in a future issue of *Lubrication Engineering.*

Detroit Section Kicks Off 1957 Program with Annual Stag Outing

Hillcrest Country Club was the scene of the Detroit Section's annual stag outing on September 15. Section officers and members are busy generating interest in the 1957 Annual ASLE Meeting among local industries for which the Detroit Section will be host.

Ontario Section Publishes 1956-57 Program

Meetings of the Ontario Section will be rotated between Toronto and Hamilton during the coming year. The September meeting was held in Hamilton, September 9 at Robert's Restaurant. Dutch Sisters Inn will be the site of the Toronto meeting on October 9. Speaker for the evening will be C. F. Smith, Vickers-Sperry of Canada Ltd., talking on Hydraulic Systems — Their Operation and Maintenance. The December 11 meeting in Toronto should provide lively discussion as four lubrication experts attempt to solve lubrication problems posed by the audience. Complete details can be obtained from the Section secretary (see ASLE Directory, this issue.)

In Memorium

Oscar L. Maag
1890 - 1956

One of the world's foremost lubrication engineers, a past president of ASLE (1947-48), past chairman of Committee D2 of ASTM, and active in ACS, SAE, and the Coordinating Research Council, Oscar Maag was stricken with a fatal heart attack on August 22.

Oscar was born in Russell, Kansas and attended high school and the University of Kansas, receiving his BS degree in chemistry in 1913 and the MS degree in 1915.

During World War I he served with the Bureau of Standards and later was employed by the Galena Signal & Oil Co. of Franklin, Pa. Mr. Maag is best known for the work he did at the Timken Roller Bearing Co. including many major improvements in industrial lubrication techniques among which was the Timken Lubricant Tester, an instrument to measure the load carrying ability of bearing and gear lubricants. The device led to the development of extreme pressure lubricants essential to the modern high speed mills employed in the production of sheet steel. He was an author of many articles and lectured extensively on lubrication. Last year Oscar retired as Chief Lubrication Engineer at Timken Roller Bearing Co. after 32 years of service. He was retained by the company as consulting engineer, and became associated as a consultant with the Ironsides Co., of Columbus, Ohio and Liverpool, England.

In April of this year he was awarded ASLE's highest award—the ASLE National Award—which carries with it honorary life membership (see Lubrication Engineering, May-June 1956 p. 179) for his achievements in the field of lubrication.

With SHELL ADC* Oilprint Analysis . . .

Part of the fleet operated by Cleveland-Lorain Highway Coach Co., Lorain, Ohio, lubricated by Shell Rotella Oil and protected by Shell ADC* Oilprint Analysis.

"Extended oil drain intervals... lower repair costs"

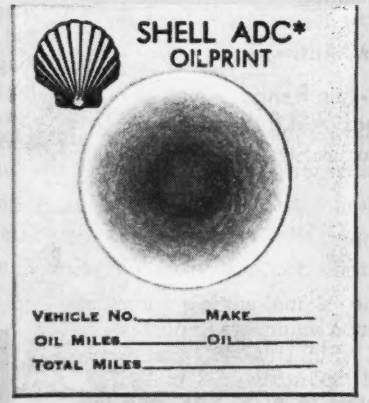
HERE'S ANOTHER transportation company that has found the Shell ADC* Oilprint Analysis a cost-saving tool of preventive maintenance. By its use, oil drain intervals have been extended safely on some new diesel coaches.

Furthermore this fast, reliable oil check has revealed many potential troubles in advance, such as oil contamination due to block fracture . . . in time to save costly repair bills. The Cleveland-Lorain Highway Coach Co. is enthusiastic about it.

The Shell ADC Oilprint Analysis enables fleet operators to test crankcase oil in the short time allotted for re-fueling and crankcase oil checks . . . mere *minutes*. It eliminates draining still-good oil and the risk of using oils loaded with contaminants.

Let us demonstrate how we can put this new cost-saving PM tool to work for you.

*Trademark



One Drop tells the Story!

The operator places just one drop of oil on the card. Analysis gives conclusive check of oil's condition.

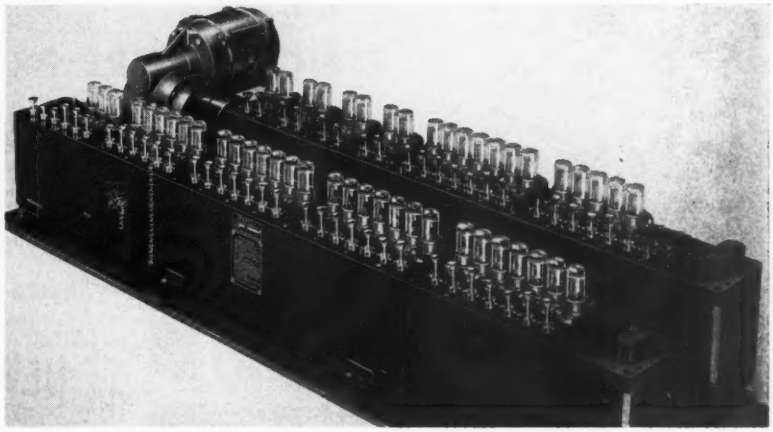
SHELL OIL COMPANY

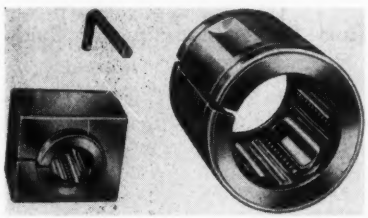
50 WEST 50TH STREET, NEW YORK 20, NEW YORK
100 BUSH STREET, SAN FRANCISCO 6, CALIFORNIA

SHELL

New Products

Vacuum-Type Pumping Unit. The special 82-V vacuum-type pumping unit, pictured right (one of over 5,000 individual models already in field use), was especially designed to meet the needs of a large compressor manufacturer, and is being installed in one of the new ammonia plants in the United States. Note that the lubricators are driven by one common gear motor and that the drive is taken from the back lubricator into the front lubricator by way of a geared shaft. The bracket which supports the lubricators incorporates an oil pan which catches the drippage from the lubricators in case of overfilling the lubricator housing. One of the big advantages of this lubricator is that regardless of how small the setting is for the oil delivery, the plunger stroke remains the same; i.e. to change the volume of oil delivered, only the position of the plunger in relation to inlet port is changed. Other advantages include reduced maintenance costs; since no fluid is required, there is no need for replacing it. (Manzel Div. of Houdaille Industries, Inc., 315 Babcock St., Buffalo 10, N. Y.)





Adjustable Diameter Linear Bearing. A new type ball bearing for linear motion is now in production in which the bearings are split longitudinally, as illustrated above, and are designed to easily provide line-to-line or slight preload fits when mounted in an adjustable diameter housing. The bearings enable the tolerance on both the shaft diameter and bearing bore to be adjusted out. In addition, the principle provides for compensation for wear that might eventually develop in severe applications. (Thomson Industries, Inc., Manhasset, N. Y.)

Teflon-Base Pipe Sealing Compound. A new chemically inert pipe joint compound that will seal practically all known highly-corrosive liquids and solvents has been developed for services up to 212° F. Known as "John Crane" Chemlon Pipe Joint Compound, its base is duPont Teflon. This material is not only impervious to all types of hard-to-handle fluids, but possesses an extremely low coefficient of friction. The latter substantially reduces wrench torque, permitting connections to be drawn up to a greater degree of tightness without undue stress or strain. (Crane Packing Co., LE-12/5, 6400 Oakton St., Morton Grove, Ill.)

Redesigned Aquatrator. Rapid, accurate determinations of moisture in a wide range of chemicals (both solid and liquid), foods, drugs, and industrial products, are made possible by the newly redesigned "Precision" Aquatrator. Utilizing the Karl Fischer reagent, which is sufficiently sensitive to allow moisture determinations as low as 0.005% and as high as 100% to be determined quantitatively, the electronic indicator shows the end point of the titration just as readily in very dark solutions as in light-colored materials and is unaffected by normal variations in line voltage. This instrument performs moisture determinations in 5 to 15 minutes which, by oven-drying or distillation methods, require from one to twenty-four hours. (Precision Scientific Co., LE-12/5, 3737 W. Cortland St., Chicago 47, Ill.)

Economy Hand Pump. A new piston-type, positive-displacement, self-priming hand pump now in production delivers 20 gpm at lower "cost per gallon" than the company's rotary vane-type hand pumps rated at 10 gpm. Features include stainless steel shaft, aluminum body and piston, corrosion-resistant valves and molded plastic bearing, and built-in strainer; fast disassembly permits easy cleaning or reversing of flow direction. Available as pump only, barrel pump, pedestal pump, or with hose and nozzle delivery, the all-corrosion-resistant moving parts make the pump suitable for handling many industrial solvents, lubes, cutting or paint oils, and soaps, waxes, and maintenance liquids. (Bulletin 3011, Bowser, Inc., LE-12/5, 1300 E. Creighton Ave., Ft. Wayne, Ind.)

Delpark Up-Flo Filter. The Delpark Up-Flo Filter with perma-

(Continued on p. 341)

NOW

EFFICIENT FIRE PROTECTION FOR HYDRAULIC SYSTEMS WITH THESE TWO HOUGHTON FLUIDS:

HOUGHTO-SAFE 620

For all normal hydraulic temperatures and bearing loads (up to 85% of all needs)

HOUGHTO-SAFE 620 is a time-proven water-base hydraulic fluid that provides maximum protection against hydraulic fires. Its efficiency is proven by more than 4 years use in industry and over 2 years in Navy carrier catapults.

HOUGHTO-SAFE 620 has no effect on standard packings used in oil or water hydraulic systems—is not toxic—and provides greater efficiency at lowest installed cost for most hydraulic systems.

THE NEW

HOUGHTO-SAFE 1020

For systems running consistently over 150°F. and for heavily loaded pumps and bearings

HOUGHTO-SAFE 1020 is a new *fortified* synthetic hydraulic fluid expressly compounded to provide greater efficiency in systems where temperatures repeatedly exceed 150°F.

HOUGHTO-SAFE 1020 provides complete rust protection; resists foaming; is stable in use and storage, low in toxicity, and high in oiliness. It's *different* from former non-aqueous fluids.

Find out today how you can now eliminate the fire hazard in any hydraulic system with the Houghton fire-resistant fluid that will provide greatest operating efficiency. Ask your Houghton Man or write to E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa.

HOUGHTO-SAFE

. . . products of

E. F. HOUGHTON & CO.

PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service . . .

ASLE Directory

NATIONAL OFFICERS

President
E. R. Booser
General Electric Co.

Vice-President at Large
J. O. McLean
Reynolds Metals Co.

Secretary
J. L. Finkelmann
Chrysler Corp., Cycleweld Div.

Treasurer
J. W. Peterson
Standard Oil Co. (Ind.)

Administrative-Secretary
W. P. Youngclaus, Jr.
ASLE National Office

Chrmn., Presidential Council
J. W. Hopkinson
Penn-Petroleum Corp.

NATIONAL DIRECTORS

A. E. Cichelli
Bethlehem Steel Co.

D. M. Cleaveland
Bendix Aviation Corp.

J. H. Fuller
E. I. duPont deNemours & Co.

W. E. Lasky
Gulf Mobile & Ohio RR Co.

C. T. Lewis
Republic Steel Corp.

J. D. Lykins
Wheeling Steel Corp.

D. W. Sawyer
Aluminum Co. of America

C. R. Schmitt
E. F. Houghton & Co.

REGIONAL VICE-PRESIDENTS

M. E. Dougherty, (Eastern)
Acheson Colloids Co.

R. F. McKibben, (Central)
National Cash Register Co.

B. H. Miller, (Canadian)
Imperial Oil Co., Ltd.

L. M. Tichvinsky, (Western)
University of California

A. B. Wilder, (Midwestern)
E. I. duPont deNemours & Co.

SECTION OFFICERS

	CHAIRMAN	VICE-CHAIRMAN	SECRETARY	TREASURER
Baltimore	J. E. Buchanan	R. L. Humphreys	C. J. Devries	W. W. Witmer
Boston	H. A. Wilson	H. G. Senning	G. T. Collatz	R. S. Jackman
Buffalo	A. Brownell	V. Steele	L. E. Locke	C. L. Miller
Chicago	R. G. Grothus	J. N. Waddell	E. W. Drummond	E. W. Drummond
Cincinnati	R. W. Smith	G. E. Brown	E. L. Curtis	E. L. Curtis
Cleveland	A. O. Anderson	E. F. Rost	J. W. Hurley	G. L. Smith
Connecticut	P. Faxon	N. E. Shirk	L. Edwards	C. E. Pratt
Dayton	E. C. Briggs	H. L. Sellers	H. A. Bradley	A. G. Horvath
Detroit	R. F.Urso	J. A. Brady	T. Cabba	C. F. Cowley
Fort Wayne	C. R. Griffith	J. W. Sites	J. M. Olson	J. M. Olson
Houston	R. DuPont	M. P. Murphy	W. S. Nicholson	T. O. Siegmund
Indianapolis	J. R. McCoy	L. E. Danford	C. M. Marlatt	C. M. Marlatt
Kansas City	R. H. Cottrell	C. L. Austin	J. D. Jenkins	C. J. Huth
Kingsport	L. Hale	T. R. Witt	H. E. Goddard	H. E. Goddard
Los Angeles	V. V. Mason	J. R. Wilcox	R. F. Connelly	R. F. Connelly
Louisville	C. A. White	R. B. Davis	J. K. Wyatt	J. K. Wyatt
Milwaukee	W. E. Elliott	J. A. Gramling	J. H. Berg	V. A. Weiss
Mohawk-Hudson	d. Apkarian	R. McBride	E. S. Preble	E. S. Preble
Montreal	A. R. Scott	C. D. Poole	J. H. Whyte	J. H. Lemeilleur
New York	D. B. Gordon	H. D. Lewis	M. M. Gurgo	F. J. Stolting
N. California	R. H. Decker	A. C. West	G. H. Hommer	L. P. Richardson
Ontario	J. F. Parker	C. I. McDougall	W. H. Mann	C. W. Fitzwilliam
Philadelphia	R. W. Clark	W. P. Finley	F. L. Heist	N. A. Bracht
Pittsburgh	W. G. Ritter	A. D. Binz	M. Parker	O. B. Rosstead
Saginaw Valley	J. R. Campbell	J. W. Mestrezat	J. A. Norton	R. P. Schreiber
St. Louis	H. W. McCulloch	G. W. Schall	D. R. Levey	D. R. Levey
Syracuse	R. Buyea	H. E. Kaye	E. J. Naughton	L. T. Crenan
Twin Cities	D. L. Heimes	J. B. McFail	C. H. Sweet	L. N. Croteau
Wheeling	C. Billingsley	S. R. Fredlock	S. J. Litten	S. J. Litten
Youngstown	J. N. Hocke	D. E. Whitehead	J. A. Weber	J. R. Lemmon

ADDRESSES OF SECTION SECRETARIES

Baltimore .....C. J. Devries, Sexton & Peake, Inc., 1025 Conn. Ave. NW, Washington 6, D.C.
Boston .....G. T. Collatz, 473 Washington St., Wellesley, Boston 81, Mass.
Buffalo .....L. E. Locke, Battenfeld Grease & Oil Co., P. O. Box 144, N. Tonawanda, N. Y.
Chicago .....E. W. Drummond, Interntl. Harvester Co., 5225 S. Western Blvd., Chicago 9, Ill.
Cincinnati .....E. L. Curtis, 3 Sylvan Lane, Cincinnati 15, Ohio
Cleveland .....J. W. Hurley, Ford Motor Co., 17601 Brookpark Rd., Cleveland, Ohio
Connecticut .....L. Edwards, Gulf Oil Corp., 68 Carmel St., Hamden, Conn.
Dayton .....H. A. Bradley, 3600 Hertland Dr., Dayton 9, Ohio
Detroit .....T. Cabba, Sinclair Refg. Co., 5060 Lakewood, Apt. 6, Detroit 13, Mich.
Fort Wayne .....J. M. Olson, 4301 SE Anthony Wayne Dr., Fort Wayne, Ind.
Houston .....W. S. Nicholson, The Texas Co., 720 San Jacinto, Houston 1, Tex.
Indianapolis .....C. M. Marlatt, Neff Engrg. Co., P. O. Box 7361, Indianapolis, Ind.
Kansas City .....J. D. Jenkins, Box 1099, Kansas City, Mo.
Kingsport .....H. E. Goddard, 407 Cutler St., Greeneville, Tenn.
Los Angeles .....R. F. Connelly, 6033 N. Camellia Ave., Temple City, Calif.
Louisville .....J. K. Wyatt, Standard Oil Co. (Ky.), 430 W. Bloom, Louisville 8, Ky.
Milwaukee .....J. H. Berg, 2537 N. 41 St., Milwaukee 10, Wisc.
Mohawk-Hudson .....E. S. Preble, Greenbush Ave., E. Greenbush, N. Y.
Montreal .....J. H. Whyte, British American Oil Co., 606 Cathcart St., Montreal, P. Q., Canada
New York .....M. M. Gurgo, Esso Standard Oil Co., 151 Hamiltonian Dr., Red Bank, N. J.
N. California .....G. H. Hommer, 1271 Mt. Diablo St., Concord, Calif.
Ontario .....W. H. Mann, D. A. Stuart Oil Co., 3575 Danforth Ave., Toronto, Ont., Can.
Philadelphia .....F. L. Heist, E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.
Pittsburgh .....M. Parker, E. F. Houghton & Co., Bessemer Bldg., Pittsburgh 22, Pa.
Saginaw Valley .....J. A. Norton, AC Spark Plug Div., GMC, Dort Hwy., Flint 4, Mich.
St. Louis .....D. R. Levey, 3292 Watson Rd., St. Louis 9, Mo.
Syracuse .....E. J. Naughton, 182 Clyde Ave., Syracuse, N. Y.
Twin Cities .....C. H. Sweet, Minneapolis-Moline Co., Box 1050, Minneapolis, Minn.
Wheeling .....S. J. Litten, Sun Oil Co., 910 Pearl, Martins Ferry, Ohio
Youngstown .....J. A. Weber, 166 N. Middle St., Columbiana, Ohio

AREA REPRESENTATIVES

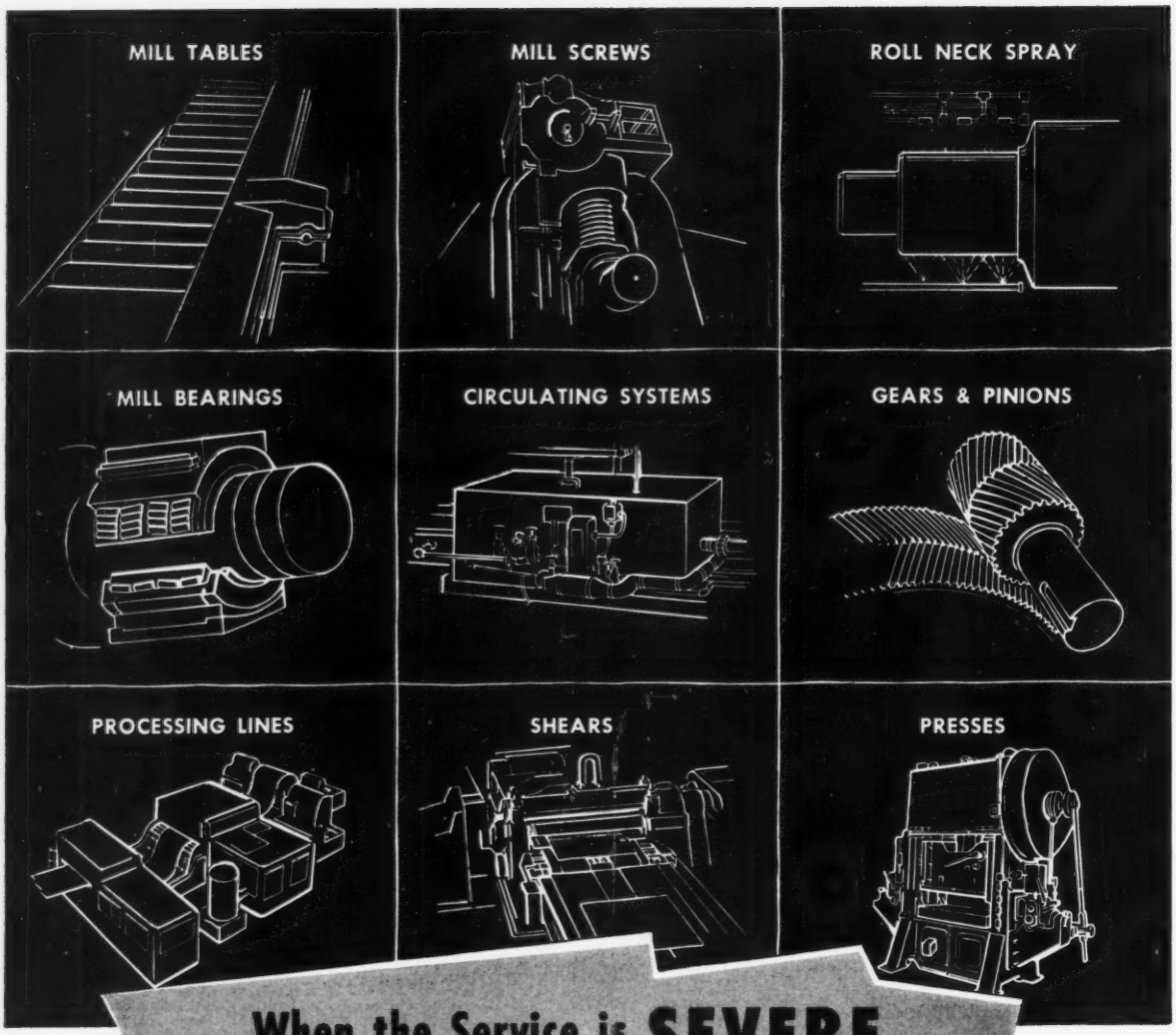
Cleveland/Youngstown .....A. H. Turner, Standard Oil Co.
Columbus .....H. W. Irion, National Refining Co.
Dayton/Cincinnati .....G. H. Leffel, D. A. Stuart Oil Co.
Kansas City/St. Louis .....C. J. Smith, Cities Service Oil Co.
Texas .....F. A. Rudolph, Sun Oil Co.
Twin Cities/Duluth/Des Moines .....R. O. Erickson, Shell Oil Co.

NATIONAL COMMITTEE CHAIRMEN

Abstracts .....W. E. Campbell, Clevite Research Center
Annual Meeting (Detroit) .....J. A. Brady, Penn-Petroleum Corp.
Annual Meeting Sites .....J. D. Lykins, Wheeling Steel Corp.
Awards .....J. H. Fuller, E. I. duPont deNemours & Co., Inc.
By-Laws .....W. H. Millett, Carbide & Carbon Chemicals Co.
Editorial .....R. K. Gould, The Texas Co.
Education .....B. G. Rightmire, Massachusetts Institute of Technology
Exhibit Arrangements .....M. L. Beardslee, General Motors Corp.
Finance .....C. C. Blaisdell, Penola Oil Co.
Handbook Advisory .....C. R. Schmitt, E. F. Houghton & Co.
Historian .....W. G. Fatch, U. S. Steel Corp.
Industrial Membership .....W. P. Youngclaus, Jr., ASLE National Office
Industrial Representative
Industry Relations
Journal Bearing Research .....E. M. Kipp, Aluminum Co. of America
Lubrication Conference .....E. E. Bisson, National Advisory Committee for Aeronautics
Membership & Admission .....B. T. Harding, Midwest Oil Co.
New Sections .....W. P. Youngclaus, Jr., ASLE National Office
Nominations .....J. W. Hopkinson, Penn-Petroleum Corp.
Program (Annual Meeting—Detroit) .....C. R. Lewis, Standard Oil Co. (Ind.)
Projects
Tellers .....R. G. Grothus, Bell & Howell Co.

TECHNICAL COMMITTEE CHAIRMEN

Technical Advisory Board .....S. R. Calish, Jr., California Research Corp.
Bearings & Bearing Lubrication .....A. A. Raimondi, Westinghouse Electric Co.
Engine Lubrication .....N. C. Penfold, Southwest Research Institute
Fluids for Metal Working .....W. J. Wojtowicz, H. A. Montgomery Co.
Gears & Gear Lubrication .....T. W. Havely, Shell Oil Co.
Hydraulics & Hydraulic Machinery .....R. Q. Sharpe, Socony Mobil Oil Co., Inc.
Lubricant Reclamation & Disposal .....A. B. Two, Ford Motor Co.
Lubrication Equipment .....E. M. Higgins, Master Lubricants Co.
Lubrication Fundamentals .....D. Godfrey, California Research Corp.
Lubrication Practices .....R. J. Torrens, Eastman Kodak Co.
Properties of Lubricants .....C. W. Nichols, Jr., Socony Mobil Oil Co., Inc.
Seals & Packings .....R. W. Blair, Chicago Rawhide Mfg. Co.



When the Service is SEVERE

—you're better off with Brooks LUBRICANTS

The unique properties of Brooks lubricants have provided outstanding service where other quality lubricants have proved inadequate. Brooks lubricants are remarkably resistant to water or moisture conditions and abrasion. Brooks lubricants are non-corrosive, adhesive, and extremely stable in long periods of production service; maintaining a *minimum* pH-ilm strength of 25,000 psi. Extended equipment service and reduced lubricant consumption can be assured in practically all severe applications.

Write for Engineering Data Bulletin on your particular application.

THE BROOKS OIL CO. 80th YEAR 1876 1956

THE BROOKS OIL COMPANY

Executive Offices and Plant, Cleveland, Ohio
Executive Sales Offices, Pittsburgh, Pa.
Canadian Offices and Plant, Hamilton, Ontario
Cuban Office, Santiago de Cuba
Warehouses in Principal Industrial Cities

AVAILABLE:
New 16 mm technicolor sound movie
THE BROOKS OIL STORY
Procedures Applications
Write for more details.

LEADOLENE · Klingfast · ROLLENE · Barcote

Lube Lines

by A. F. Brewer*

LUBRICANT BY-PRODUCTS FROM THE MEAT PACKING INDUSTRY. The extent to which the meat packing industry contributes products which are used as constituents in lubricating oils and greases, often is not fully realized. To be sure, it is well known to all that lard oils and tallow are important constituents in some steam cylinder oils, cutting oils, and in compounding certain greases; but as long as they are available at reasonable cost to the lubricant manufacturer, percentages usually are of little interest. Let's look at some figures:

The most important by-products of the packing industry are edible and inedible fats. According to *The Technology Review* (February 1956, "Dollars From Wastes," by Harry W. vonLoesecke) they can amount to as much as 18 percent of the total sales value of the output of the plant. From the inedible fats an improved process has been developed for producing oleic acid (commonly called "red oil"). This by-product is an important constituent of textile lubricants and greases for certain types of service. Authorities in the U. S. Department of Agriculture, where this process was developed, estimate the annual value as approaching a million dollars. And this pertains to only one of the by-products of the packing industry which concern the lubrication engineer. Others, such as lard oils and tallow, and the lately developed substitute for palm oil in hot dipping of steel plate, total up to a very respectable volume of net-back to the packer. In brief, the manufacturers of lubricants are highly important customers of the meat packers.

DRY LUBRICATION. In the fields of lubrication and machine design, there is a very definite place for those non-petroleum materials which are assistants to, or replacements for, conventional metal combinations and petroleum-base lubricants. Certain of these materials are derived as petrochemicals from the products of the oil refinery. Others are natural substances or, more strictly, of synthetic chemical nature. We have in mind those solid materials which have been found to be so well suited for service where durability with little or no added lubrication is a factor. In other words, the products themselves are possessed of lubricating ability and minimum frictional effect.

Dry lubrication is not a new idea; it antedates many of us who today are so concerned with the theory and application of modern lubricants. In its most elemental form, it simply means running two moving surfaces in actual contact with each other, with the hope that their possible dissimilar nature or the presence of "oiliness" in the atmosphere will keep them from wearing too much or too rapidly. This is oftentimes customary practice in the operation of detachable chains which are used in conveyor and materials handling service, where the links are exposed to, or in contact with, dusty or abrasive substances such as ore, coal, or rock products. Less wear in the long run has been found to develop than where a lubricant of necessarily heavy body might be used, which would tend to absorb abrasive dust and possibly develop a grinding compound effect. The ancients took advantage of the same idea by using wood as the supporting hub for chariot wheels running on wood or iron axles.

The modern conception of dry lubrication, however, presumes that one or both of the operating materials which must come in moving contact will possess some lubricating value. Here again, wood bearings came into the picture; sometimes there was the possibility of cooling and reduction of wear by water as with water wheels; later it was found practicable to impregnate wood such as oak or maple with oil, thereby to forestall the need for further lubrication in service. While the oil-impregnated wood bearing and our present day porous metal types of bearings should not strictly be regarded as dry materials from a lubrication viewpoint, they do fit into the picture in regard to development of the idea.

Then, there are the so-called dry lubricants, also referred to as solid lubricants. Of these, sulfur, graphite, white lead, and zinc oxide have been used for years, primarily as assistants to fluid lubrication. The classic idea of adding a pinch of sulfur to the oil to stop a noisy bearing, or to cool down one which is running too hot, is historical. The use of graphite, in turn, either in dry form or mixed with oil or grease is equally as renowned for its beneficial effects in reducing friction.

The Bentones and Molybdenum Disulfide are more recently developed solid lubricants which are distinctive for their stability at high temperatures. Bentones have the specific properties of good water-resistance, so they are well suited for service where considerable water wash may be expected. Molybdenum Disulfide, in turn, has good film tenacity and low coefficient of friction, so it is effective in reducing friction at high sliding velocities. Boron Nitride is another solid lubricant which also has excellent stability at high temperatures. This material sometimes is referred to as white graphite by reason of its unctuous nature. It is used as a component with silicone type lubricants, the latter serving as a carrier to distribute the boron nitride to the surfaces to be lubricated. By itself, however, this material does not adhere well to metal surfaces.

"Teflon," tetrafluoroethylene fiber, is among the

(Continued on p. 344)

*Consultant, and Author of "Basic Lubrication Practice."

MOLYKOTE®

CHECKS "STICK-SLIP" ON A GRAND SCALE

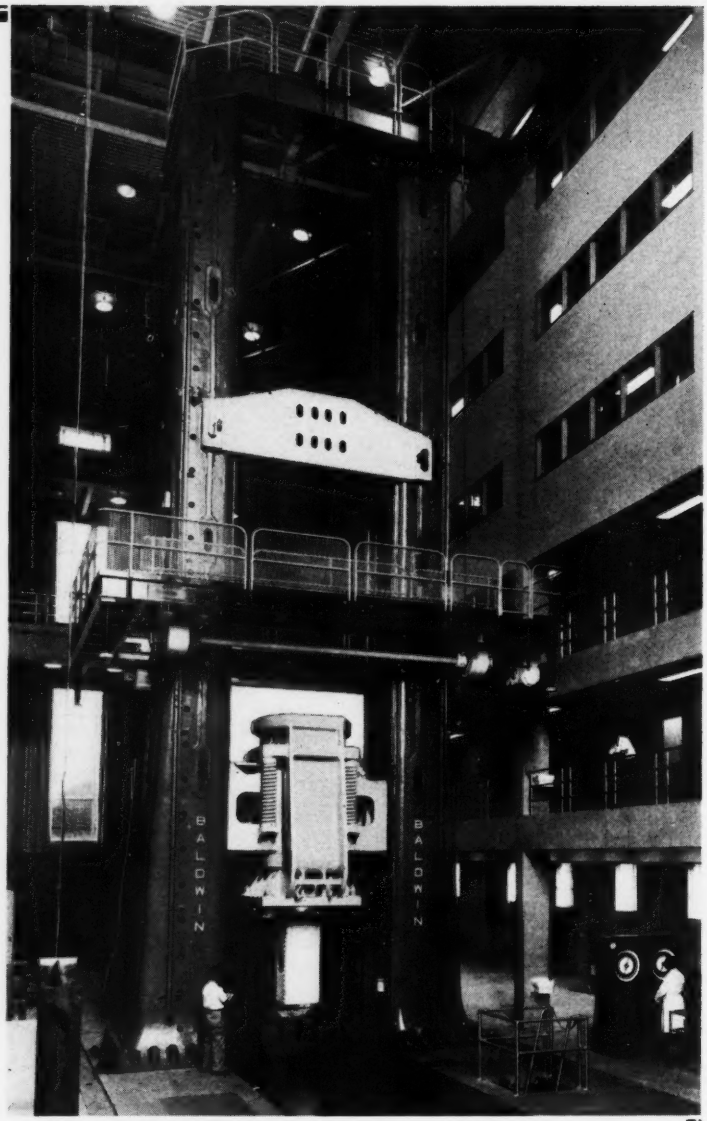
When engineers of Baldwin-Lima-Hamilton Corporation designed and built this mammoth 5,000,000 pound universal testing machine for Lehigh University, they realized from years of experience that extreme testing pressures could cause destructive "stick-slip" action in the test specimen grips and the loading screws.

That is why MOLYKOTE Lubricant was generously applied to both the grips and the screws before the first trial specimen was broken in this giant universal tester.

Baldwin engineers, as well as engineers throughout industry, have come to depend upon MOLYKOTE Lubricant in extreme pressure applications.

MOLYKOTE is manufactured from the purest molybdenum disulfide powder available to industry today. It is compounded under laboratory supervision to retain this purity in the manufacturing process and has achieved an enviable reputation for overcoming the toughest lubrication problems in industry.

MOLYKOTE Lubricant is distributed throughout the world, wherever industry faces the obstacles of providing adequate lubrication in extreme pressure and extreme temperature applications.



5,000,000 pound B-T-E Universal Testing Machine installed in Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa. Built by Baldwin-Lima-Hamilton Corporation, Eddystone, Pa.

If you are not receiving the new LUBRICATON NEWSLETTER, write today on your company letterhead and we will gladly add your name to our mailing list.

The **ALPHA MOLYKOTE** *Corporation*

Main Factories: 65 Harvard Avenue, Stamford, Conn.
71 Arnulfstrasse, Munich 19, Germany

Lubrication in the Presence of Nuclear Radiation*

Some effects of pile radiation on the lubrication of bearings and gears have been investigated. Three special lubricants, shown from previous studies to have unusual radiation stability, were used. Apparatus of two types was operated at 285° F. in a nuclear pile. Motor-driven journal bearings were run at 80 rpm through a gear train. Air turbines supported by ring-oiled ball bearings were operated at about 10,000 rpm. Each test was duplicated in the absence of radiation. Radiation damage markedly shortened the useful life of the lubricants.

J. G. Carroll & R. O. Bolt
California Research Corp.
576 Standard Ave.
Richmond 1, Calif.

INTRODUCTION

Atomic power plants have been considered for some time for the generation of electric power in central stations and for the propulsion of ships, aircraft, railroad engines, and even automobiles. Early studies showed conventional lubricants which might be used in or near such power plants to suffer severe radiation damage. The development of radiation resistant lubricants was, therefore, begun by California Research Corporation early in 1948. Initial work involved a general study of the effects of pile radiation on organic fluids. Factors such as radiation dose, radiation dose rate, and exposure temperature were investigated, as was the influence of radiation on oxidation, on catalysis of decomposition by metals, and on the action of chemical additives. This initial research was followed by functional test work on lubricant formulations which had shown promising radiation resistance.

The over-all investigation was divided into three parts: (1) *Static Irradiations*, in which small amounts of fluids were exposed to radiation in containers open to air; (2) *Oxidation Tests*, in which the formulations developed in the first tests were screened further both in the presence and absence of radiation; and (3) *Lubrication Tests*, in which the more promising lubricants were similarly screened. The present article covers the last of these parts and is the first unclassified description of the work.

Table I identifies the fluids used in the lubrication work. Each oil was tested in low- and in high-speed units, both in the presence and the absence of pile radiation.

LOW-SPEED LUBRICATION TESTS

These tests were conducted to determine whether pile radiation caused reversible changes in the over-all lubrication process or whether effects would be confined to permanent radiation damage to the organic lubricant. Loaded ball and journal bearings and gears were operated in the Oak Ridge graphite pile; torque measurements during pile operating and down periods were obtained, along with final wear measurements. Comparative data were then secured in reference tests outside the pile.

Description of Apparatus

The apparatus shown in Figure 1 was driven by a 27-volt, 10,000-rpm, permanent magnet DC motor (Item 1), which rotated test specimens operating in a bath of lubricant. The motor was mounted vertically and supported on two metal balls so that it pivoted freely. Power was transmitted through the gear box (Item 2) to the output journal (Item 4), which was loaded by air pressure applied to split steel bushings (Item 8). This load was applied from a bellows (Item 5) actuated by air pressure. The torque produced by the load applied to the bushings caused the motor to pivot on its support balls. This pivot force was balanced by an air stream which flowed through the small orifice (Item 6) and impinged on the torque arm (Item 3) mounted on the motor body. The air pressure required to keep this torque arm "floating" on an electrical contact was a measure of motor torque.

The speed of the motor was reduced through the gear train in the ratio of 71 to 1. Constant output speed was maintained at about 80 rpm by controlling input voltage. Speed was measured by electrical pulses which resulted from the passage of the commutator segments over the brushes. These pulses were transmitted along one of the thermocouple wires to an oscilloscope. Strip heaters were provided in the block assembly of Figure 1. Temperature control was maintained by input voltage adjustments.

Figure 2 shows the gears, shaft, and bearings of a test rig. The bronze shaft and steel bushings were standard test parts from the Almen Wear Test Machine.[1] The

J. G. Carroll

R. O. Bolt

*This research was sponsored by the Fairchild Engine & Airplane Corporation under contract to the U. S. Air Force.

This paper was presented at the ASLE 11th Annual Meeting, Pittsburgh, April 4, 1956.

Table I

Lubricants Employed

Code	Base Fluid	Additives (% by Weight)
A	Di(2-ethylhexyl) Sebacate	20% 1-Methylnaphthalene, 5% Didodecyl Selenide, 2% Iodobenzene, 0.01% Quinizarin
B	Poly(propene oxide)-B (two ether end groups)	5% Didodecyl Selenide, 2% Iodobenzene, 0.01% Quinizarin
C	Octadecylbenzene	5% Didodecyl Selenide, 6% Iodobenzene, 0.01% Quinizarin

motor armature support bearings were of 3.5-mm and 5-mm bore. In all tests, the parts shown in Figure 2 were weighed prior to operation of the unit and reweighed at the end of the test to yield wear data in terms of weight change.

TEST PROCEDURE

Three of the assemblies of Figure 1, each containing 50 ml of a different lubricant, were operated in the Oak Ridge pile. The steel bushings (Item 8) were completely covered by this quantity of fluid. The test on Oil B was run for 105 hours. The units lubricated with Oil A and Oil C operated for 95 and 55 hours, respectively. Motor commutator failures prevented further operation in the latter two cases.

Temperature was maintained at 285° F. in all these runs. Torque readings were taken at frequent intervals, and close watch was maintained during pile down periods so that any abrupt changes would be noticed as they occurred. Such abrupt changes would indicate short-lived reversible effects on the over-all lubrication process as opposed to permanent changes in only the lubricants. Loads were carefully controlled by adjustment of the air pressure

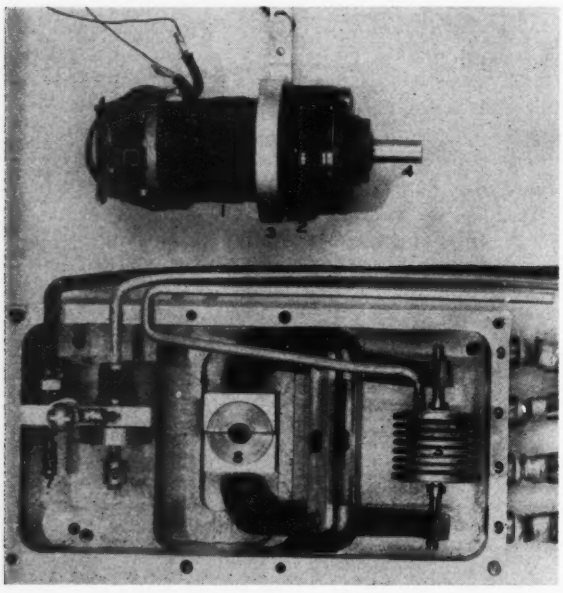


Figure 1. Low-speed bearing test unit. Key: (1) drive motor, (2) gear box, (3) torque arm, (4) bronze output shaft, (5) loading bellows, (6) torque measurement orifice, (7) motor connections, (8) steel bushings, (9) heater connections.

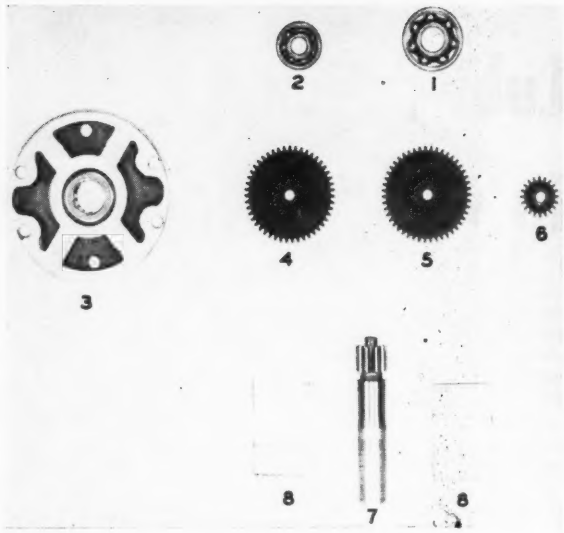


Figure 2. Weighed parts of low-speed bearing test unit. Key: (1) lower armature bearing, (2) upper armature bearing, (3) end bell and needle bearing, (4, 5, 6) reduction gearing, (7) bronze shaft and drive spline, (8) steel bushings.

to the load-actuating bellows. Reference runs were conducted in which the operating conditions were identical with those of the pile runs, except for the presence of radiation. Thus, data from the reference and pile runs could be compared.

RESULTS

TORQUE DATA

Figure 3 shows the torque data obtained in the reference and in the pile runs. Motor torque in the latter was significantly higher. For Oil B this holds true only initially since the torque in the pile test decreased below that of the reference run at about the one-third point (40 hours). For Oil A and Oil C, the torque data indicate that the lubrication process was adversely affected by pile radiation and/or the fluids became poorer lubricants in the pile. For Oil B, the torque data show an improvement due to the radiation.

There was a pile shutdown period between 68.9 and 69.9 hours while the units containing Oil A and Oil B were operating. At this time the motor torque was observed as the neutron flux was abruptly reduced. No change in the operating characteristics of the two units occurred during this period. This shows that no sudden change in the over-all lubrication process took place. Instead, the comparison of the torque curves for the reference and the pile runs suggests that permanent changes were taking place gradually in the lubricant during irradiation.

Examination of the motors from the pile tests showed that thick lacquer coatings (probably from oil vapors) had built up on the commutators and carbon brushes. These coatings apparently acted as insulators which broke electrical contact between commutators and brushes with the Oil A and Oil C units. This caused their early shutdown in the pile.

WEAR DATA

In lubrication tests of this type, wear data sometimes mean more than torque data in evaluating the lubri-

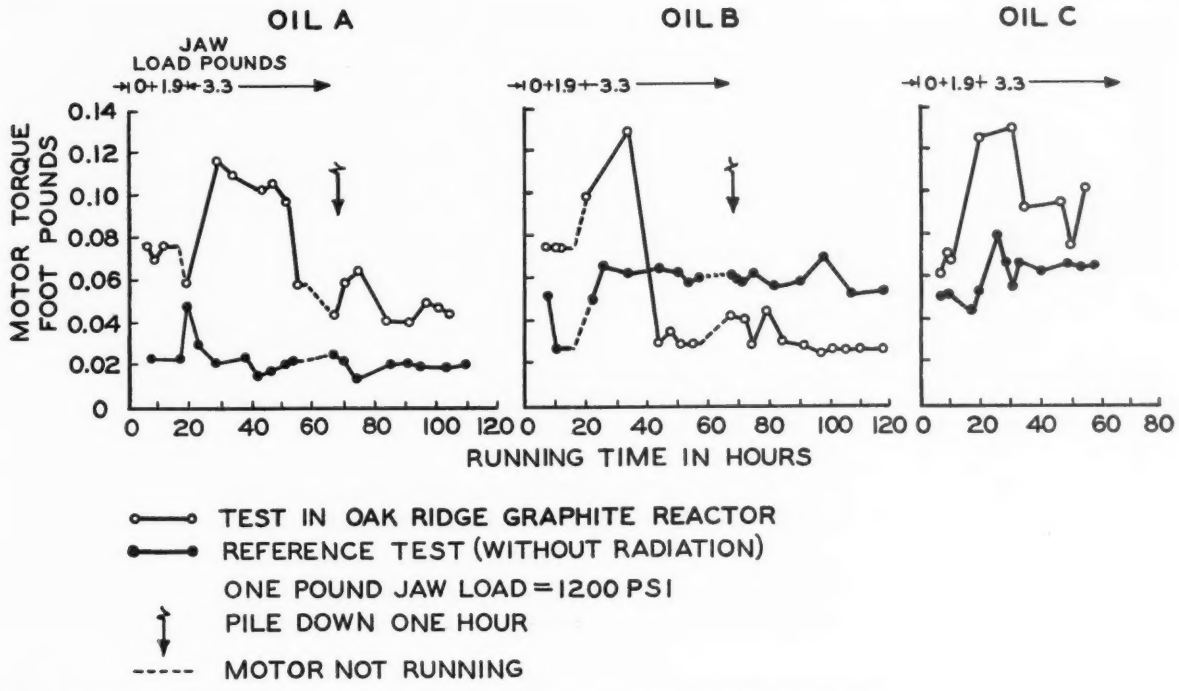


Figure 3. Low-speed lubrication tests; comparison of motor torque with and without radiation.

cant. The data of Table II show that in both the reference and pile tests weight changes were generally minor, except for the bronze shafts. These lost as much as 1% of their original weight. In the pile tests the relation between the weight losses of the bronze shafts associated with the Oil B, Oil A, and Oil C is 1 to 1.5 to 2.6, respectively. Compared to the reference tests, weight losses for Oil A and Oil C were markedly higher in the pile tests, although Oil B showed lower wear in the pile.

As shown in Table III, the wear data and the torque data both signify that the lubricating ability of Oil B improved on irradiation. The other two oils became poorer lubricants on exposure.

FALEX TEST RESULTS corroborate the improvement in wear properties of the Oil B on irradiation. In this work a sample of uncompounded base oil [poly (propene oxide) with one ether and one hydroxyl end group] similar to that of Oil B was irradiated. Table IV summarizes the results of tests on the irradiated and the original fluid in the Falex Lubricant Tester.[2]

In the Falex Extreme-Pressure Test, the film strength of a lubricant is measured. A one-fourth inch shaft rotates in a pair of steel "V" blocks which are covered with the test lubricant. Load is gradually applied until the oil film ruptures and metal seizure occurs. This is taken as the point of failure and is shown by scoring and high torque. Irradiated Oil B showed appreciably improved film strength in this test over its original value. The Falex Wear Test also utilizes a one-fourth inch shaft turning in a pair of steel "V" blocks. A relatively low weight loss of the shaft is the index of good antiwear properties of the lubricant.

LUBRICANT DETERIORATION

Table V summarizes data on the radiation induced thickening of the three oils in the low-speed experiments. In the reference runs, the three fluids showed significant changes in viscosity; however, these are minor when compared to the thickening experienced in the pile tests. The viscosity increases in the latter tests were quite high considering the low radiation dosage. This may indicate that thickening was catalyzed by the action of the metals despite

Table II
Low-Speed Tests
Weight Change on Wearing Parts

Machine Parts		Weight Change, Milligrams					
Name	Weight, Grams	Oil A		Oil B		Oil C	
		Ref.	Pile	Ref.	Pile	Ref.	Pile
Three Bearings	18	+9.9	−14.2	+0.5	−2.4	+6.2	−19.1
Three Gears	8	+2.7	+1.4	+0.5	+2.1	+0.1	+2.5
Two Steel Bushings	21	+1.7	−10.1	−1.0	−7.3	+0.5	−5.3
Bronze Shaft (and drive spline)	8	+6.4	−45.6	−70.0	−29.8	−16.2	−78.2
Total	55	+20.7	−68.5	−70.0	−37.4	−9.4	−100.1

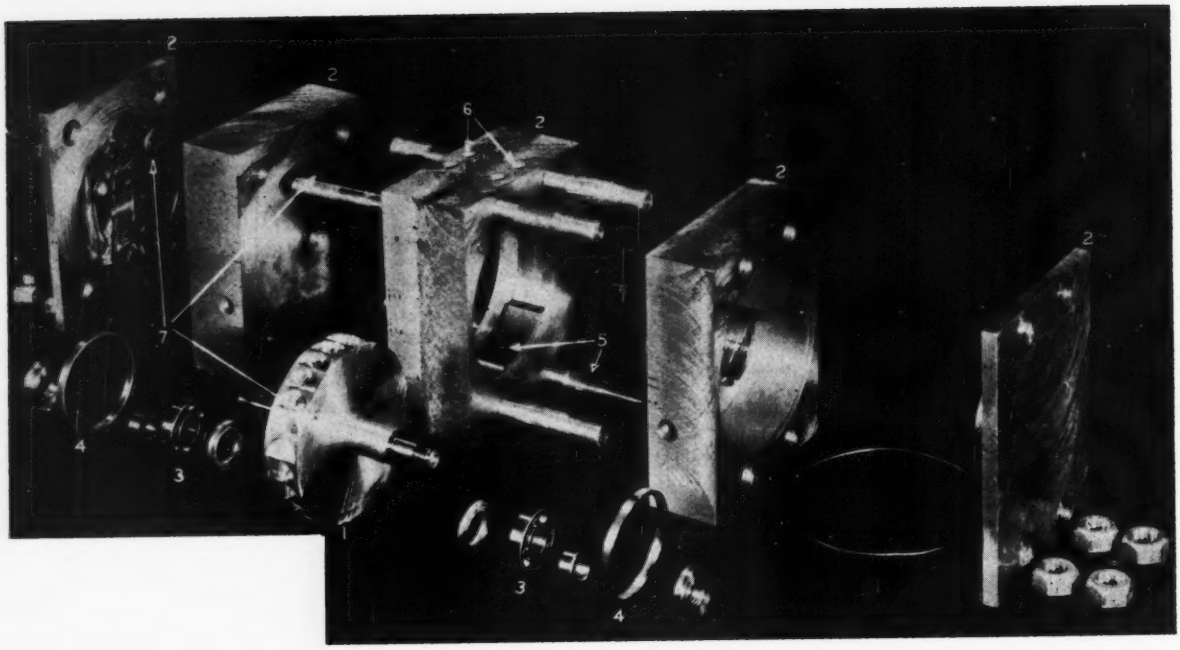


Figure 4. High-speed bearing test unit. Key: (1) turbine rotor, (2) housing components, (3) rotor bearings, (4) oil rings, (5) air inlet, (6) air outlet, (7) components of speed pickup.

the presence of the metal deactivator (quinizarin) in the oil. In the pile tests, the 100° F. viscosity increased as follows: Oil B - 75%; Oil C - 81%; Oil A - 262%. In the tests without radiation, the increase was considerably less but still significant. The 100° F. viscosity increase was about 16% for both Oil B and Oil C and was 41% for Oil A. Thus, even the exposure in the absence of radiation at 285° F. with metal catalysts present had an appreciable effect.

The wear and torque data discussed previously showed that the lubricating properties of Oil B improved on irradiation. The question arises as to the dependence of this improvement on the viscosity of the oil under test. The data of Table V show the lack of influence of viscosity. Thus Oil A and Oil B have about the same viscosity after irradiation yet both torque and wear data (see Table III) show Oil B to be superior to Oil A.

HIGH-SPEED LUBRICATION TESTS

The high speed tests were conducted primarily to determine the effect of pile radiation on fluids lubricating high speed bearings. Air turbines supported by ball bearings were operated at about 10,000 rpm in the Oak Ridge pile. Used lubricating fluids from these were compared with duplicate fluids which were subjected to identical test conditions, but in the absence of radiation.

Description of Apparatus & Test Procedure

The high speed test unit, which is shown in Figure 4, consisted of three components: an air-driven turbine

Table III

Summary of Wear and Torque Data in Low-Speed Tests

Lubricant	Weight Loss of Bronze Shaft, mg		Torque, Ft-Lb			
			Pile		Reference	
	Pile	Ref.	Max.	Min.	Max.	Min.
Oil A	45	+6	0.115	0.040	0.055	0.014
Oil B	30	70	0.130	0.029[a]	0.072[b]	0.029
Oil C	78	16	0.130	0.065	0.080	0.043

[a]Lower value predominant, [b]Higher value predominant

Table IV

Falex Tests on Oil B-Type Base Oil

Description of Test	Original Oil	Irradiated Oil[a]
1. Falex Extreme-Pressure Test: (Load applied at rate of 250 lb per minute; steel on steel; 19.6 fpm; room temp.) Load at Failure, lb	1250	2250
2. Falex Wear Test: (500-lb jaw load; 30-minute test at 19.6 fpm and room temp.; steel on steel) Wt. Loss of Steel Shaft, mg	10.8	3.5

[a]Irradiated in Oak Ridge graphite pile at 86° F. and 75% maximum flux for a dosage whose slow neutron portion was 1.6×10^{18} neutrons/cm^2.

Table V

Lubricant Deterioration in Low-Speed Tests[a]

Lubricant	Viscosity, Centistokes					
	100° F.			210° F.		
	Orig.	Ref.	Pile	Orig.	Ref.	Pile
A	8.5	13.0	32.8	2.5	3.5	6.5
B	17.7	20.0	31.0	4.3	4.8	6.1
C	9.8	11.4	17.7	2.7	2.9	3.9

[a]Exposed in pile at 285° F. and a radiation dosage whose slow neutron component was 4×10^{17} neutrons/cm^2.

(Item 1) and two separate oil sumps. Each of the two 10-mm bore (R-6) turbine bearings (Item 3) was lubricated from its sump by an oil ring (Item 4) which turned on the shaft. The entire unit was made of 2S aluminum, except for the bearings and the steel sleeves which supported them on the rotor shaft. In order to maintain the test oil at the desired temperature of 285° F., the air which drove the turbine was preheated. This was done by passing a low voltage-high amperage electric current through the 20-foot aluminum tubes which supplied air to the apparatus.

The speed of the turbine was measured by an electrical impulse which was induced once each revolution when a small magnet in the turbine wheel passed a fixed coil (Item 7) in the cover plate. The impulse was transmitted along one of the thermocouple wires to an oscilloscope. Matching this unknown impulse to first, second, and third multiples of 60 cycles/second on the oscilloscope allowed the adjustment of turbine speeds to 3,600, 7,200, and 10,800 rpm, respectively. The speed of the turbine was controlled at these approximate levels by varying the inlet air pressure.

Three of these test rigs, each containing a different lubricant, were operated in the pile. Fifteen milliliters of the test oil were placed in each of the two sumps of a unit prior to insertion in the pile.

Results

Lubricant Deterioration

Table VI summarizes the viscosity data for the lubricants used both in the pile runs and in the runs in the absence of radiation. The viscosity changes indicate that Oil B was damaged the least in the pile experiments with an increase in the 100° F. viscosity of about 125%. The value for Oil A is about four times this figure, while that for Oil C is in between. The relative order of viscosity increase in the reference tests is approximately the same; i. e., Oil B increased in 100° F. viscosity by 10%, Oil A by about 40%, and Oil C was intermediate. As in the case of the low speed tests, it is evident that the damage in the reference exposure alone is appreciable in an operating unit at 285° F. Part of this may be due to the loss of the more volatile components of the fluids, i. e., iodobenzene and/or 1-methylnaphthalene.

Direct comparisons with the oils of the low speed tests on the basis of viscosity increase are not valid due to the difference in radiation dosages involved. However, adjustment of the viscosity increases to a common radiation dosage allows the conclusion that viscosity increase was roughly equal in the two types of tests.

Appearance of Test Apparatus

The high speed in-pile tests resulted in greater amounts of sludge and carbon formation than were observed in the reference tests. These deposits were noted on the walls and sides of the sumps and on the bearing housings. The bearings of the in-pile experiments were closer to failure at the completion of the tests. This was due primarily to lacquer deposits on the bearings themselves rather than to mechanical damage, such as scoring, galling, or pitting and represents the effect on the bearings of the degraded oil. Rockwell "C" hardness[3] tests were run on the bearings after exposure. A slight amount of softening was indicated.

Table VI

Lubricant Deterioration in the High Speed Tests[a]

Lubricant	Viscosity, Centistokes					
	100° F.			210° F.		
	Orig.	Ref.	Pile	Orig.	Ref.	Pile
A	8.8	13.3	58.0	2.5	3.6	8.8
B	17.7	19.5	40.3	4.3	4.6	6.4
	17.7	19.6	33.9	4.3	4.6	5.8
C	9.8	11.6	34.3	2.7	2.8	5.9

[a]Exposed in the pile at 285° F. for a radiation dosage whose slow neutron component was 6×10^{17} neutrons/cm^2.

Summary

High speed antifriction and low speed journal bearings lubricated with special fluids were operated in the Oak Ridge graphite pile. A temperature of 285° F. and a radiation dose whose slow neutron component was about 5×10^{17} neutrons/cm^2 were employed. None of the bearings was run to mechanical failure at the operating temperature so that this dosage does not indicate the limit of operability. On the basis of the limited tests reported here, the following conclusions can be drawn:

1. The over-all lubrication process does not appear to change with the sudden decrease of neutron flux, such as occurs during pile shutdown. This indicates that no short-lived changes in this process occur.

2. The presence of pile radiation markedly shortens the useful life of a lubricant. Compared to lubricant change in the presence of pile radiation, that suffered in the absence of radiation under identical conditions is minor.

3. The compounded sebacate fluid is a better lubricant than the octadecylbenzene in the presence of pile radiation, even though the former fluid undergoes greater deterioration.

4. Wear data from bench tests on an irradiated poly(propene oxide) tend to confirm the results of the functional tests, which indicate that the wear properties of this type of oil improve upon irradiation.

5. Of the materials reported here, the compounded poly(propene oxide) is the most satisfactory lubricant in a pile atmosphere. This is based on wear and torque data, appearance of the lubricated parts, and oil deterioration as measured by viscosity change.

Bibliography

1. Clower, James I., *Lubricants & Lubrication*, McGraw-Hill, New York, 1st Edition, 1939, p. 145.
2. Bulletin No. 3, 12, 121, 122, Faville-LeValley Corp., 105 W. Adams St., Chicago, Ill., Feb. 3, 1948.
3. Committee E-1, ASTM Standards — Year 1949, Part I, "Ferrous Metals," 1950, p. 1267.

12th ASLE Annual Meeting & Exhibit

April 15-16-17, 1957 **Sheraton-Cadillac Hotel, Detroit**

Current Research in the Bacteriology of Soluble Oil Emulsions*

H. Pivnick, L. R. Sabina, R. Samuel-Maharajah & C. K. Fotopoulos
University of Nebraska, Department of Bacteriology
Lincoln, Nebraska

This report discusses current research in the bacteriology of soluble oil emulsions. The areas of research mentioned concern pathogenic bacteria, disinfection, oxidation of oils, hydrogen sulfide production, and taxonomy and physiology of pseudomonads from oil emulsions. The research indicates that (1) some pathogenic bacteria grow readily in soluble oils, (2) disinfection is an extremely complex problem with many variables, (3) oils vary in their susceptibility to microbial oxidation, (4) microbial reduction of inorganic sulfur occurs readily, and (5) relatively little is known of the microbial population of soluble oil emulsions.

Bacteria are found in most soluble oil emulsions and synthetic cutting fluids used in industry. The oils, when delivered by the manufacturer, are sterile. However, when mixed with water, they may readily support microbial growth. [1–5] The growth of bacteria indigenous to the emulsions results in oxidation of components of the oil, lowering of the pH and production of malodorous compounds. Studies of these microbial activities may indicate methods of improving the formula of soluble oils or of controlling the growth of contaminating bacteria.

The predominating types of microorganisms found in emulsions used in industry belong to the genus Pseudomonas.[1, 2, 6, 7] However, members of the genera *Achromabacter, Aerobacter, Escherichia* and *Bacillus*, as well as yeasts and molds, have been reported.[1] Also, both areobic[7] and anaerobic[8] members of the genus *Vibrio* have been isolated. Coliform bacteria, indicative of fecal pollution, are found regularly in about half of the samples of used emulsions obtained from industry [9, 10] but usually comprise less than one per cent of the microbial population.

Pathogenic bacteria, such as those causing boils, have been isolated occasionally from cutting fluids. [11, 19] They do not grow in this medium, [7, 11] however, and survive for only a few days. It appears that the main cause of boils and related afflictions is an invasion of the defatted or abraded skin by potential pathogens which are normal residents of the skin.[14, 15]

Attempts to control microbial activity in emulsions is carried out with varying degrees of success. For example, one sample of emulsion, obtained from an automobile manufacturer, was accompanied by a letter which stated that bacteria caused no trouble in their emulsions because they added disinfectants. But this sample was found to contain a high bacterial count and over 100,000 coliform bacteria per ml. The most commonly used methods of control employ pasteurization[20] or the addition of chemical disinfectants. *But frequently the cardinal rule of sanitation, cleaning before adding the disinfectant, is entirely neglected.*

In order to carry out controlled studies of microbial activity, it is necessary to isolate pure cultures from the mixtures of bacteria found in the emulsion. These cultures, either singly or in mixtures, are then inoculated into sterile emulsions or components of emulsions. It is only by such methods of investigation that the cause of microbial breakdown of soluble oils will be discovered.

Work in progress in our laboratory in the field of microbiology of soluble oil emulsions can be divided into five areas.

1. Growth of pathogenic bacteria which cause typhoid fever and related enteric diseases.
2. Disinfection of soluble oil emulsions.
3. Oxidation of soluble oil emulsions and components of soluble oils.
4. Reduction of inorganic sulfur compounds in soluble oil emulsions.
5. Study of the taxonomy and physiology of bacteria isolated from soluble oil emulsions.

GROWTH OF PATHOGENS

Coliform bacteria are harmless inhabitants of the intestinal tract. But their presence in oil emulsions may be considered with some gravity because the fecal matter which introduces these microorganisms may also contain pathogenic bacteria of the enteric fever group. Sanitarians would not hunt for enteric fever bacteria in oil emulsions because of the difficulty of isolating them. They would, however, consider that any emulsion containing coliform bacteria was polluted with fecal matter and potentially dangerous.

Pathogenic bacteria of the enteric fever group grow readily in soluble oil emulsions[16] and may survive for many weeks.[11] In the presence of the microflora indigenous to industrially-used emulsions, the pathogens are gradually killed off (Figure 1) but this is a prolonged process. Exposure in the oil for several weeks does not reduce the virulence of these pathogens when tested by injection into mice.

It is impossible to state, at the present time, whether or not the ability of such organisms to grow in soluble oil

*This investigation was supported, in part, by a research grant, RG-4266(c), from the National Institutes of Health, United States Public Health Service.

This paper was presented at the ASLE 11th Annual Meeting, Pittsburgh, April 5, 1956.

emulsions presents a potential public health hazard. When one considers the frequency with which coliform bacteria are found, the production of aerosols as a result of plant operations, and the rapidity of microbial growth, one cannot disregard the matter entirely. We would like to emphasize, however, that we have never encountered in the scientific literature any record of enteric fever spread by cutting oils.

DISINFECTION

Whenever microbes become a nuisance, methods of control are instituted. In soluble oil emulsions, these methods have been limited to destruction of the microorganisms by heating the emulsion and by chemical disinfection.

The practice of heating the emulsion (pasteurization) to destroy bacteria is limited because microbes can regain entrance to the emulsion, and within two or three days may be as numerous as they were before the pasteurization process.[15] Disinfection poses more problems than the mere killing of bacteria. The disinfectants may be sensitizing and cause dermatitis.[13] They may be added indiscriminately and excessively,[12] or they may be added in such small amounts as to be entirely useless, thus deluding the plant operator. Moreover, there is a possibility that they may selectively destroy one type of bacteria which normally acts antagonistically to pathogenic bacteria without destroying the pathogens. This artificial upset of the natural order may thus allow pathogens to grow, unhindered by their normal competitors.

No evidence for the preceding statement is available in the field of soluble oil microbiology, but analogous situations have been reported in the medical journals. For example, antibiotic therapy of humans prior to oral surgery, or for other reasons, may reduce the normal microbial content of the intestine to such an extent that antibiotic-resistant pathogenic bacteria, ordinarily kept in check by the normal intestinal microflora, grow rapidly with serious consequences.

Although soluble oils are sterile when sold by the manufacturer, they may readily become contaminated under conditions of use and support microbial growth. Most manufacturers, therefore, are vitally concerned with control of the contaminating bacteria. In one way or another, they usually hear about bad odors and broken emulsions even though faulty sanitation in the machine shop may be as responsible as any intrinsic quality of the oil. For these reasons a survey of leading oil manufacturers was carried out in 1954 in an attempt to find out their policies with respect to disinfection of soluble oils.

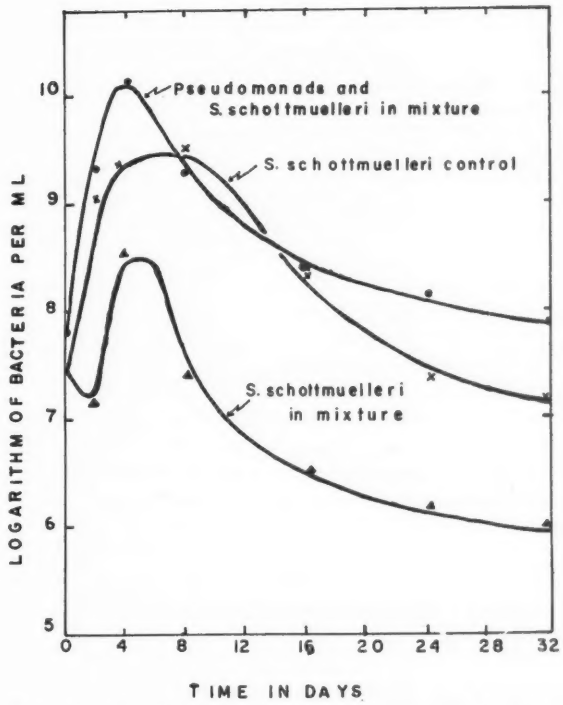


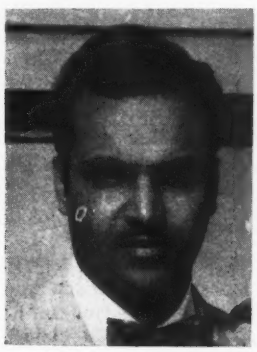
Figure 1. Growth and decline of a pathogenic bacterium (*Salmonella schottmuelleri*) in the presence of pseudomonads in oil emulsion.

The answers to our enquiry indicated that there was no uniform policy in the industry. Some companies stated that disinfectants should be added by the manufacturer; others believed that, because the soluble oil may be diluted with 10 to 100 parts of water, a disinfectant added by the manufacturer would be too concentrated at a 1:10 dilution of the oil or too weak at a 1:100 dilution. They advocated addition of disinfectant by the user. The third opinion was that disinfectants are unnecessary if sanitation is adequate.

Most companies produce soluble oils containing disinfectants, though it is our opinion that many of these are of limited value. Our studies show that several soluble oils containing disinfectants will grow as many bacteria as those without disinfectant when diluted with 100 parts of water. Of several soluble oils containing disinfectants, only one showed active bactericidal properties, and this property was maintained less than one week under conditions simulating those found in industry.

H. Pivnick

L. R. Sabina



R. Samuel-Maharajah

C. K. Fotopoulos

Our survey elicited information about disinfectants which were to be added by the users, and samples were obtained and tested by methods simulating industrial conditions. Other compounds, not previously used in soluble oil emulsions were also tested. It was found that disinfectants, used according to the manufacturers' recommendations, often had little effect in decreasing the total microbial content of the emulsions. Studies concerned with the selective destruction of certain groups of bacteria, or the control of disagreeable odors, have not yet been undertaken.

Disinfectants added by the machine shop operator may be required in higher concentration when an oil is diluted 1:10 than when the same oil is diluted 1:100. Some disinfectants which have been tested in our laboratory in a concentration of one part of disinfectant to 1000 parts of emulsion gave adequate bacterial control when the emulsions contained one per cent of soluble oil. The same concentration of disinfectant was useless in emulsions containing 10 per cent of soluble oil. Apparently some component of the oil inactivates some disinfectants.

Aeration of an emulsion and circulation through iron chips may inactivate a disinfectant. For example, one oil contained a disinfectant which killed all bacteria added to the emulsion within one day. The same emulsion was reinoculated 8 days later with sufficient bacteria to give 10^7 organisms per ml., and within 24 hours of reinoculation the microbial population had increased to 2.4×10^7 bacteria per ml.

When planning a disinfection program, the plant engineer must realize that the addition of disinfectants is not a cure for all of the ills which beset soluble oil emulsions. Sanitation, the adequate cleansing and disinfection of systems prior to filling with fresh emulsion, is a necessary beginning. Intelligent addition of disinfectants in adequate but not excessive amounts may be of additional value. Such disinfectants should be non toxic to the plant operator under the conditions of use. It appears that a well-planned disinfection program would benefit from an alliance of engineer, microbiologist, and toxicologist.

THE MICROBIAL OXIDATION OF SOLUBLE OILS

The breakdown of soluble oil emulsions is, in part, due to the microbial oxidation of the hydrocarbons with a concomitant drop in pH. The components of the emulsifier system, however, are probably more susceptible to oxidation than the hydrocarbons. Our research has indicated that with a given species of bacterium, different soluble oils will be oxidized at different rates. Also, different bacterial species differ in their capacity to oxidize a single soluble oil.

Emulsifiers are oxidized at different rates and most of them appear to be more susceptible to oxidation than a pale oil. Of several emulsifiers examined, triethanolamine oleate was the most susceptible to oxidation, while petroleum sulfonate was the most resistant. Pale oil was not oxidized when subjected to conditions used for the microbial oxidation of emulsifying agents.

REDUCTION OF INORGANIC SULFUR

In microbial respiration inorganic sulfur, in a form more oxidized than sulfide, may act as an electron acceptor. The electron donor (material being oxidized) may be hydrogen or such organic compounds as the microorganism is capable of metabolizing. The oxidative reactions result in a production of energy which is used by the cell. Several species of bacteria are capable of obtaining energy while using such inorganic sulfur compounds as sulfate, thiosulfate, and sulfur as electron acceptors.

There are many opportunities for inorganic sulfur compounds to appear in soluble oils. The manufacture of petroleum sulfonates results in the retention of some inorganic sulfate, while some waters used in the emulsion contain sufficient sulfate to produce hydrogen sulfide in appreciable amounts. The bacteria which reduce sulfate are obligate anaerobic members of the genus Vibrio,[18] but it is possible that additional types may be found capable of bringing about the same reaction. Organic sulfur compounds of the petroleum sulfonate type are relatively resistant to conversion to hydrogen sulfide.

Thiosulfate, although not likely to be a component of emulsifiers, has been studied in our laboratory with respect to reduction by bacteria. Thiosulfate may be reduced by the same bacteria which reduce sulfate but, in addition, there are many other types of bacteria which can reduce this compound.

Elemental sulfur, which may be present in some sulfurized oils, is readily reduced by many common heterotrophic bacteria. Sulfur may also arise from the atmospheric or microbial oxidation of sulfide.

It is possible that a sulfur cycle, similar to those existing in soil and water, will be found in soluble oil emulsions. The sulfur cycle represents microbial oxidation of reduced sulfur compounds to sulfate under aerobic conditions, and the reduction of oxidized sulfur compounds to sulfide under anaerobic conditions. Our research indicates that reduction occurs readily, but up until now we have not concerned ourselves with microbial oxidations of sulfur.

TAXONOMY & PHYSIOLOGY

Taxonomy is the science upon which the classification of the biological world rests. The botanists and zoologists classify plants and animals almost entirely on the basis of morphology. But the bacteriologist, because of the small size of the organism which he studies, uses morphology only to a limited extent. The chief basis for microbial taxonomy is a study of microbial physiology.

Many of the physiological studies routinely used in bacteriological laboratories are generally satisfactory for identification of isolated organisms with known species. When studying some isolates, however, the usual tests are not adequate and additional investigations of nutrition, metabolic pathways, and pigments, are carried out. These exacting and time-consuming studies are especially important when a new species is being described or when an original published description is inadequate. In some cases it is necessary to obtain reference organisms and study them simultaneously with the bacteria under investigation.

Our studies of taxonomy and physiology are concerned with the following organisms. *Pseudomonas formicans* was first isolated from sewage by Crawford[17] who briefly described and named it in 1954. Our isolates, obtained from a sample of emulsion in 1953, are being studied in considerable detail. The results of our work should extend our knowledge of this organism considerably.

Pseudomonas oleovorans was isolated from soluble oil emulsions by Lee and Chandler and first described and named in 1941.[2] This organism is isolated consistently

from soluble oil emulsions but the isolates differ slightly from those described by Lee and Chandler. Comparison of our isolates with cultures of *P. oleovorans* obtained from the National Type Culture Collection (N.T.C.C.) indicate either that Lee and Chandler made an error in their description, or that the cultures of Lee and Chandler which we obtained from the N.T.C.C. are mutants of the original isolates.

Pseudomonas species A, isolated in our laboratory from soluble oil emulsions, appears to be a new species. Its carbohydrate metabolism is so unusual that, to date, no comparable metabolic activity has been reported in the scientific literature. *Pseudomonas species B,* isolated in our laboratory from soluble oil emulsions, differs from most recorded pseudomonads by the production of a water-soluble brown pigment. It appears to be a hitherto undescribed organism.

In addition to the above species, upon which considerable investigation has already been carried out, we are beginning a study of isolates which metabolize inorganic sulfur.

At the present time our knowledge of the microbiology of soluble oil emulsions is infintesimal in relation to what is still unknown. Like any branch of science, the more one studies, the more one appreciates how much more there is still to be studied. In 15 or 20 years we may be able to give a more unified picture of the complex changes occurring in this fascinating medium.

BIBLIOGRAPHY

1. Duffett, N. D., Gold, S. H., and Weirich, C. L., "Growth of bacteria in cutting oils," *J. Bacteriol., 45,* 1943, 37.
2. Lee, M. and Chandler, A. C., "A study of the nature, growth and control of bacteria in cutting compounds," *J. Bacteriol., 41,* 1941, 373-386.
3. Liberthson, L., "Bacteria in cutting oils," *Lub. Eng., 1,* 1945, 103-106.
4. Westveer, W. M., "Cutting oil disinfection," *Mod. San.,* Jan. 1951, 31.
5. Fabian, F. W. and Pivnick, H., "Growth of bacteria in soluble oil emulsions," *Appl. Microbiol., 1,* 1953, 199-203.
6. Pivnick, H., "*Pseudomonas rubescens,* a new species from soluble oil emulsions," *J. Bacteriol., 70,* 1955, 1-6.
7. Pivnick, H., "The nutrition and factors affecting the growth of bacteria in soluble oil emulsions," 1952 Thesis, Michigan State College, East Lansing, Mich.
8. Davis, J. B. and Updegraff, D. M., "Microbiology in the petroleum industry," *Bacteriol. Rev., 18,* 1954, 215-238.
9. Pivnick, H. and Fabian, F. W., "Coliform bacteria in soluble oil emulsions," *Appl. Microbiol., 2,* 1954, 107-110.
10. Pivnick, H. Unpublished data, 1953.
11. Bennett, E. O. and Wheeler, H. O., "Survival of bacteria in cutting oil," *Appl. Microbiol., 2,* 1954, 368-371.
12. Schwartz, L., "Dermatitis from cutting oils," *Nat. Safety News, 44,* No. 5, 1941, 34, 36, 78-9.
13. Schwartz, L., "Coolants needn't be dangerous," *Am. Mach., 93,* Aug. 1949, 90-92.
14. Campbell, P. C., "Dermatitis from cutting oils and solvents," *Ind. Hyg. Newsletter, 7,* No. 10, 1947.
15. Shapiro, H., "Cutting oil dermatoses," N. Y. State Dep't. of Labor, Division of Ind. Hyg. and Safety Standards, *29,* No. 2, 1950, 5-8.
16. Pivnick, H., Engelhard, W. E. and Thompson, T. L., "The growth of pathogenic bacteria in soluble oil emulsions," *Appl. Microbiol., 2,* 1954, 140-142.
17. Crawford, I. P., "A new fermentative pseudomonad, *Pseudomonas formicans," J. Bacteriol., 68,* 1954, 734-738.
18. Bunker, H. J., "A review of the physiology and biochemistry of the sulfur bacteria," *Chemistry Research,* Special Report No. 3, Dep't of Sci. and Ind. Res., H. M. Stationery Office, London. 1936.
19. Albaugh, R. P., *Ohio Pub. Health J., 9,* No. 4, 1918, cited by Kober, G. M. and Hayhurst, E. R. in *Industrial Health,* Blakiston's Son and Co., Philadelphia. 1924.
20. Anonymous, "Cutting oils, emulsions and drawing compounds," *Safe Practices Pamphlet, No. 44,* National Safety Council, Inc., Chicago. 1921.

ACKNOWLEDGMENT. The authors wish to thank the many petroleum manufacturers and machine shops for samples of soluble oils and used emulsions. They also extend their appreciation to industry for assistance and interest in this research.

COMMENTARY

E. O. BENNETT, UNIVERSITY OF HOUSTON

Our observations on the normal flora of soluble oil emulsions concur in a general way with those of Dr. Pivnick. Various species of Pseudomonas were commonly observed, although we have also isolated *Escherichia coli* and *Aerobactor aerogenes.* One emulsion obtained from industry contained predominantly *Aerobacter,* and it was resistant to all of the bacterial inhibitors we were using at that time.

There is one additional observation that may be of interest. We have studied one sample of used soluble oil emulsion that contained 710,000,000 bacteria per ml. This is the highest count ever reported for emulsion oils.

PRESENCE & GROWTH OF PATHOGENS IN CUTTING OILS

We have studied the effects of various types of straight oils and emulsion oils on bacterial survival. For purposes of convenience, the straight oils were divided into heavy, medium, and light oils.

Gram-positive pathogenic bacteria as a group do not appear to present a problem as they do not survive in cutting oils. Members of the Gram-negative group, particularly those causing gastrointestinal disturbances, constitute the major source of trouble. From the standpoint of bacterial inhibition, the Gram-negative bacteria are the most difficult to inhibit.

Pathogenic bacteria do not survive in heavy straight oils; in fact, there is evidence to indicate that no bacteria will be found in this type of oil.

Gram-negative pathogenic bacteria can survive in medium straight or light straight cutting oils for four or five weeks, and for indefinite periods in emulsions.

We have previously reported the isolation in almost pure culture of *Micrococcus pyogenes* var *aureus* from an emulsion taken from a plant where several workers were suffering from cutaneous infections at the time the sample was taken. The organism could not be recovered from the oil after the sample had been in the laboratory for one week.

Previous attempts to isolate Enteric pathogens from used cutting emulsions have not been successful. Dr. Pivnick has shown that these organisms are often antagonized by the oil and other bacterial flora. Consequently, they are present only in minute quantity when the sample is received in the laboratory. When we are examining an oil for Enteric pathogens, we subject it to a gravitational force of approximately 23,000 G. for about 20 minutes. This will pack most of the bacteria and debris in the bottom of the tube and, thus, concentrate the pathogens which might be present. We inoculate the packed bacteria onto special selective, differential and enrichment media. As a result of this technique we have been able to isolate a *Paracolon* and a *Salmonella* from used cutting emulsions. The *Salmonella* was isolated from the same emulsion at three different times. Possibly this technique will be helpful to others interested in this problem.

While studying the survival power of *Salmonella typhosa* in cutting emulsions, one member of our group contracted a severe case of typhoid fever. At the time of his infection, the organism had been cultured in the oil for over four weeks. There seems to be no doubt that the infection was contracted from the emulsion oil. This laboratory accident indicates that bacteria can retain their ability to infect man in cutting emulsions for considerable periods of time.

DISINFECTION OF CUTTING EMULSIONS

During recent years a great deal of effort has been expended in attempts to find bacterial inhibitors suitable for use in cutting emulsions.

In a search for a bacterial inhibitor for this purpose, two major lines of approach are available. First, through a knowledge

of the metabolism of the organisms in question, compounds may be selected which will specifically interfere with, or prevent, metabolism to the point where multiplication ceases and spoilage of the oil is eliminated. Second, in the absence of such specific information on the metabolism of the invading organism, our only recourse is to determine the ability of a wide variety of substances to inhibit multiplication of the bacteria in question. The latter method is commonly known as screening and is the method which has been most productive for finding chemotherapeutic agents of clinical usefulness.

In the case of cutting emulsions, because of our limited knowledge regarding the metabolism of the spoilage organisms, the only method that offers promise of early success is random screening. This does not mean, however, that the metabolic approach should be abandoned.

Any screening procedure involves, to a high degree, the element of chance. The desired active compound may be found within the first ten tested, or may not be encountered until many hundreds have been studied. For the same reason, the amount of labor expended is very great because, out of all of the tests performed, the only really useful test is that one which detects or indicates the active substance for which we are searching.

The major effort of our laboratories has been directed toward screening bacterial inhibitors for use in emulsion oils. This work has resulted in the study of several hundred different compounds as possible cutting oil inhibitors.

Our objective was to develop a testing procedure which would thoroughly test the inhibitor under circumstances as similar to industrial conditions as was practical. Ultimately, a two-stage testing procedure was developed which has given considerable success in connection with industrial research projects. First, a screening test is carried out to determine potential inhibitors that might be effective in emulsion oils and to eliminate the many compounds that are unsatisfactory. Sterile mixtures of emulsion and inhibitor are inoculated with used cutting emulsion collected just prior to use. Collection of the used emulsion just before use is very important, because the bacterial flora will change considerably both in numbers and types of organisms even when stored in the cold.

The inoculated inhibited emulsions are then mechanically agitated on a laboratory shaker at room temperature for 7 days. Immediately after inoculation, and at 24-hour intervals thereafter, the tubes are studied for the presence of viable bacteria using routine bacteriological procedures. Inhibitors which can kill all inoculated bacteria within the 7 day period are then studied more extensively in the second phase.

In the second phase of the testing procedure, large open jars containing 3,000 ml. of emulsion and inhibitor are inoculated with a small quantity of used emulsion. These jars are open to aerial contamination and are aerated. The number of bacteria in each unit is determined twice each week, and the study is usually continued for as long as the oil remains sterile. The most effective compounds are then studied under actual industrial conditions.

We first studied compounds marketed as commercial cutting oil inhibitors. None of the numerous commercial cutting oil inhibitors studied were able to inhibit all bacteria for a significant period of time. In several instances, the emulsion oil treated with these inhibitors contained more bacteria than the uninhibited controls, indicating that some commercial cutting oil inhibitors may actually contain substances that favor bacterial growth.

It became apparent that other bacterial inhibitors should be studied in an attempt to find effective emulsion oil inhibitors. The question often arises as to the basis on which one should select compounds for testing. Because of the nature of a screening program, there should be no basis for selection except availability and possibly cost. The purpose of the screening program is apt to be defeated when an attempt is made to find a rational basis for the selection of substances. This follows from the fact that a screening program is necessary only because of the absence of any rational basis for the selection of substances for test. The random selection of compounds to be tested should be adhered to as strictly as possible.

Our initial study involved 51 compounds. We found that the phenylphenates, chlorophenates, bis-phenols, amines, and quaternary ammonium compounds were generally ineffective as cutting oil inhibitors. Only a few compounds in these groups showed any activity. We found that the quaternary ammonium compounds in some instances were stimulatory to bacterial growth in cutting emulsions. Of the 51 compounds studied, 6 had potential application as cutting oil inhibitors.

One of the most interesting observations we have obtained from our studies is that very slight chemical modification of a compound may drastically affect its inhibitory activity in cutting emulsions. For example, tris (hydroxymethyl) nitromethane was completely inhibitory for the entire test period of 60 days, but tris (hydroxymethyl) aminomethane was effective for only 1 day. Another example was the case of 2,4,5 trichlorophenol and 2,4,6-trichlorophenol which were effective for the entire test period, while 2,3,4,6-tetrachlorophenol was effective for only 1 day.

We have found in many instances that a bacterial inhibitor will be effective in one emulsion oil and completely ineffective in another. For example, Pivnick and Fabian (1953) using a different cutting oil than the one studied by us found that 1,3-dichloro-5, 5-dimethyl hydantoin and 2,4,6-trichlorophenol were ineffective. These compounds, however, proved very effective in the cutting oil used in our investigation in the same concentration. It has been observed in our laboratories that each formulation of cutting emulsion must be studied individually with inhibitors. Just because a compound has been reported to be an effective cutting oil inhibitor does not mean that it is effective in all formulations. We strongly disagree with the attitude that bacterial inhibitors should be added by the user rather than the manufacturer, unless the user is carrying out an inhibitor testing program and has found that the inhibitor is effective in the specific cutting emulsion being used.

From our studies we believe that bacterial growth in cutting emulsions may be reduced or controlled in three ways:

1. Formulation of the cutting oil so that it offers maximum resistance against bacterial oxidation.

2. Use of a water oil ratio that offers the greatest resistance to the development of large bacterial populations.

3. Use of a bacterial inhibitor which has been shown to be effective in the specific emulsion oil.

It must be remembered that an inhibitor will not always be effective in every situation. A large bacterial population is continually changing through mutation. If the conditions are optimum, mutants may develop that are resistant to the inhibitor and the emulsion will spoil.

We feel that the destruction of pathogenic bacteria in cutting oils offers no problem. Of all bacteria, the pathogens are easiest to kill, due to their dependence on other living organisms for survival and the effect parasitism has had on their physiological activities. On the other hand, the *Pseudomonas* group is the most difficult to inhibit, due to its numerous alternate pathways of metabolism and adaptive abilities. Therefore, any inhibitor which will inhibit the growth of *Pseudomonaiae* will inhibit the growth of the pathogens.

THE MICROBIAL OXIDATION OF SOLUBLE OILS

At the present time little is known about the physiological activities of bacteria in oil emulsions. This is unfortunate because once we have elucidated the mechanism by which bacteria oxidize the emulsion, then bacterial inhibitors may be chosen more intelligently to stop the process.

One of the most important prerequisites for physiological studies with bacteria is a standard inoculum. We have tried to keep the bacterial population of emulsion oils constant for long periods of time so that a series of experiments could be compared with each other. Unfortunately, we have not been able to develop a standard inoculum to our satisfaction. The first method of preservation studied was quick freezing. Samples of emulsions containing 26 million organisms were frozen at —70° C. and stored in an ice chest. After 24 hours the emulsion contained less than 1,000 organisms/ml. Samples stored under refrigeration showed a 55 per cent reduction of viable bacteria after 9 days. Samples stored at room temperature showed a reduction of 68 per cent after 9 days. We have had to rely on keeping an inoculum growing in the laboratory at all times.

We have had occasion to study the bacterial contents of cutting emulsions for many months, and have observed a day by day fluctuation in the bacterial populations giving a cyclic effect. We interpret this phenomenon as an indication that the oxidation of cutting emulsions may take place in several stages or growth cycles, and may involve several different genera, species, or mutants of one species. If this assumption is correct, the mode of oxidation of cutting emulsions may be quite complex. Work is beginning in our laboratory on this problem.

At one time we had occasion to perform total nitrogen determinations on several different emulsion samples. Nitrogen is

an essential element needed for the synthesis of protein, yet the nitrogen content of several emulsions was very low. One emulsion sample (1-25 dilution) had a nitrogen content of about 3.5 micrograms per ml, yet this sample could support bacterial populations of 30 or 40 million organisms for several months. This indicates the possibility that nitrogen fixation may be taking place in the emulsion oil, and work is underway to prove or disprove this point. If microorganisms are capable of incorporating atmospheric nitrogen in the presence of hydrocarbons, some interesting possibilities become apparent — for example, the use of bacteria with waste fractions of petroleum to produce valuable nitrogen containing chemicals particularly, agricultural chemicals.

Lubrication Abstracts

(This is the seventh in a series of abstracts of translations of Foreign articles on lubrication, by Henry Brutcher. Copies of the full translations are available, at the indicated prices, by writing Mr. Brutcher at P. O. Box 157, Altadena, Calif.)

Cold Rolling of Phosphated Steel Strip, by W. Lueg & K. H. Treptow; "Stahl und Eisen," Vol. 75, No. 17, 1955, pp. 1085-92; 14 figs., 1 table, 4900 words. Development of phosphate coating process. Experimental steels and procedure. Influence of phosphate coating (several types) on roll force (in tons) and roll work (in ft-lb) in rolling thin strip on a 12-high Rohn stand (25/64" dia. rolls); and heavy-gage strip on a stand having a roll diameter of 7.83 in. — 0.10% C, and 1.10% C steel strip. Effect of pressure per unit area on performance of phosphate coatings; data on phosphate-coated steel strip compared with uncoated strip. Mechanical properties of strip as affected by phosphating. (Order No. 3583, price $9.80)

New Method of Determination of Coefficient of Sliding Friction & Its Application to the Study of Absorptional Lubrication, by G. I. Epifanov, F. P. Soloshko & P. A. Rebinder; "Doklady Akademii Nauk SSSR," Vol. 99, No. 5, 1954, pp. 801-804; 3 figs., 1700 words. Critical comment on current methods of measuring sliding friction. Principle of new method which prevents elastic vibrations in the measuring system; details on the proposed apparatus (Fig. 1). Nature of variation in frictional force with time and rate of mutual displacement of surfaces in contact, with the new set-up (Fig. 2). Results of preliminary experiments; procedure; data on effect of increase in quantity of surface-active substances (methyl alcohol; octyl alcohol; cetyl alcohol; stearic acid present in soln. in benzene; also aq. soln. of sodium oleate) on frictional force when mutual sliding occurs. (Order No. 3603, price $3.80)

Study of Corrosion & Wear Resistance of Calorized Steel, by S. G. Bogdanov; "Metallovedenie I Obrabotka Metallov," No. 3, 1955, pp. 25-31; 9 figs., 2 tables, 2500 words. Corrosion resistance of steel specimens calorized at various temperatures and for various lengths of time, when exposed to 50% HNO_3, HCl, H_2SO_4, picric acid, water vapor above 3% salt solution and, at high temperatures, to reducing and to oxidizing atmospheres. Calorizing compound used. Results of frictional-wear test; testing procedure. Comparison with Cr-coated and with as-normalized uncalorized steels. Effect of quenching and tempering subsequent to calorizing upon resistance to wear and corrosion. Behavior of calorized steel after upsetting and continued heating for various times. Conclusions: promise of calorizing for improved frictional wear resistance at high temperatures, and for other applications. Best calorizing temperature and time. (Order No. 3684, price $4.85)

Soundless External Dry Friction of Metals at Low Sliding Speeds, by N. F. Kunin & G. D. Lomakin; "Zhurnal Tekhnich Fiziki," Vol. 24, No. 8, 1954, pp. 1361-66; 5 figs., 1 table, 2300 words. Study of effect of velocity and temperature upon soundless friction. Classification of types of friction. Development of equations, on the basis of hypotheses about plastic flow of a metal at isolated microcontacts, for the variation of the coefficient of soundless friction with sliding speed and with time of contact, both of which satisfactorily fit existing experimental data. Authors' equation developed for the relation between the coefficient of soundless friction for high and low speeds, and the "dynamic coefficient of compression," likewise agrees with measured values of the coefficient of soundless friction at various temperatures between —180 C. (—290 F.) and +210 C. (+410 F.), for tin, copper, and aluminum sliding on iron or steel. (Order No. 3698, price $4.90)

Effect of Residual Stresses in Surface of Metals upon Wear Resistance, by P. E. D'yachenko & T. V. Smushkova; "Vestnik Mashinostroeniya," Vol. 35, No. 3, 1955, pp. 38-40; 3 figs., 1600 words. Lack of consistent literature data on effect of residual stresses in metal surfaces on wear resistance. Authors' study of influence of such stresses (tensile and compressive) in surface zone, 40-200 microinches thick, of steel rings upon the latter's wear resistance, and of variation of residual stresses and strain hardening of surface zone while subject to wear. Experimental procedure in setting up surface stresses (by high-speed machining), measuring their magnitude, and testing the specimens for wear. Wear curves (Fig. 1); distribution of residual stresses (Fig. 2). Interaction between preexisting and wear-produced stresses. Change in stress distribution induced by wear (Fig. 3). (Order No. 3713, price $3.60)

Influence of Surface-Active Agents on the Dimensions of Chip Elements (in Cutting), by G. I. Epifanov; "Doklady Akademii Nauk SSSR," Vol. 104, No. 1, 1955, pp. 68-71; 2 figs., 1 table, 1200 words. Study of effect of various "active" cutting fluids on size of individual slip elements of metal chips (obtained by planing) and on cutting force and its variation during cutting operation (Fig. 1: cutting-force vs. cutting-distance diagrams for duralumin). Cuting fluids: methyl alcohol; oleic acid; ethyl laurate; carbon tetrachloride; metals cut: dural; technically pure iron; copped. Size of slip elements of sectional chips obtained in dry cutting as against cutting in the fluids mentioned (Fig. 2: photographs of the chips from technically pure iron with juxtaposed cutting force vs. cutting-distance diagrams). (Order No. 3719, price $2.90)

NEW ASLE JEWELRY

Lapel pins and tie clasps featuring the new insignia, gold detail on a blue background with white lettering, are now available through the local Sections or National Office. The lapel pin is also being offered as a free premium to all members getting a new member. *Details are available through the Sections or National Headquarters.*

Lapel Pin **$1.50**

Tie Clasp **$3.50**

Capillary Viscometry of Lubricating Grease

L. C. Brunstrum & R. H. Leet
Standard Oil Co. (Indiana)
Research Department
Whiting, Indiana

Detailed knowledge of the viscosity or flow resistance of grease is necessary in attacking practical and theoretical problems. Measurement of flow rates and pressures through capillaries is not difficult but, because of the complex nature of the flow, interpretation of results is.

Interpretation may be made mathematically in five ways: The commonest is that of the ASTM method, which prescribes the apparatus but ignores several recognized inaccuracies; the observations are treated as though grease were a fluid and lead to an "apparent viscosity." Another way, which may be applied to observations from many capillary viscometers, leads to viscosity at the capillary wall only; the results do not differ greatly from "apparent viscosity." A third way calculates yield value and mobility on the premise that grease flows like a Bingham plastic; tables of dimensionless constants simplify the calculations. A fourth way uses a simple power equation. A fifth way takes a theoretical approach and determines an equation from flow data through Eyring's relaxation theory for viscous flow.

The choice depends upon the problem. For specifications and empirical relations in lubrication problems, "apparent viscosity" and viscosity at the capillary wall may be used. Yield value and mobility could be used for calculating pressure drops in pipes as well as for specifications. The power equation may be useful in predicting pressure losses in pipe lines from capillary data. Eyring's equation may permit calculating flow in pipes and correlating flow behavior with such factors as size, shape, weight, distribution, and surface properties of thickener particles.

NOMENCLATURE

A	Constant characteristic of grease, Powell-Eyring
a	Dimensionless group, McMillen
B	Constant characteristic of grease, Powell-Eyring
b	Radius of unsheared central plug, cm
c	b/R, dimensionless
D	Diameter, cm
F	Shear stress $PR/2L$, dynes/cm^2
f	Yield value, dynes/cm^2
G	Equals $K8^{n-1}$
g	Gravitational constant
K	Constant of Metzner
k	Viscometer constant
L	Length of capillary or pipe, cm
m	Mobility, $1/\eta_p$
N	Reynolds number
n	Constant in power equation
P	Pressure, dynes/cm^2
p	Pressure to initiate flow, dynes/cm^2
Q	Volumetric flow rate, ml/sec
R	Radius of capillary or pipe, cm
S	Shear rate, Hagen-Poiseuille $4Q/\pi R^3$
S_w	Shear rate at the wall, sec^{-1}
v	Linear velocity cm/sec
dv/dr	Shear rate, sec^{-1}
α	Dimensionless group
β	Dimensionless group
γ	Dimensionless group
η	Viscosity, poises
η_a	Apparent viscosity, poises
η_p	Plastic viscosity, poises
η_w	Viscosity at the wall, poises
μ	Constant characteristic of grease, Powell-Eyring
ρ	Density, gm/ml
σ	Absolute shear stress, dynes/cm^2
Φ	A function of
ϕ	Fanning friction factor

This paper was presented at the ASLE 11th Annual Meeting, Pittsburgh, April 5, 1956.

INTRODUCTION

One of the defining characteristics of lubricating grease is the ability to flow. Under most conditions, the nature of this flow is complex. Detailed knowledge of the flow resistance, or viscosity, is needed in attacking practical and theoretical problems. Both accurate measurements and correct mathematical interpretations are necessary to index viscosity.

The most common instrument for measuring viscosity is the capillary viscometer. Many different viscometers have been used successfully. Measurement of flow rates and pressures through capillaries is not difficult.

Interpretation of results, however, is not easy. Five ways of mathematically interpreting observed flow rates and pressures have been devised. Which should be used to define the flow of grease for both practical and theoretical purposes? Does any provide results that can be used generally? The questions come easy; the answers come hard. To answer them, a review is needed of what we know about measuring flow rates and pressures in capillary viscometers and about intepreting these measurements.

VISCOMETERS

At a given temperature, three variables affect the flow of grease through capillaries: rate of flow, pressure neces-

L. C. Brunstrum

R. H. Leet

sary to maintain flow, and dimensions of the capillaries. These variables are measured in different ways in different viscometers.

Viscometers of Arveson[2] and the ASTM[1] allow pressure measurements at constant flow rates through capillaries of several radii. The grease is forced through the capillary by a floating piston actuated by a hydraulic system.

Viscometers of Singleterry,[21] Blott, [4] and Marusov[12] provide for reciprocating movement of the grease through the capillary. These instruments have the advantage of measuring changes in viscosity occurring because of changes in the grease during prolonged shearing. In the first two, flow is timed while a constant pressure is applied; in the last, the flow rate is fixed and the pressure is measured.

These and other viscometers [3, 5, 9, 17] lead to values of pressures and flow rates in capillaries of known dimensions. Corrections peculiar to each viscometer must be made to provide sound data for interpretations.

TYPES OF FLOW

Flow equations are usually based on some ideal system. Three systems may be applicable: one based on a Newtonian liquid, one based on a Bingham plastic, and one on a pseudoplastic.

If capillary flow is completely laminar, the ratio of the shearing stress, F, to the rate of shear, dv/dr, equals a constant, called viscosity, η. According to Newton's equation

$$\eta = \frac{F}{dv/dr} \tag{1}$$

where v is the linear velocity and r is the radius of the capillary. For Newtonian flow in a capillary, Poiseuille's integration[18] applies,

$$\eta = \frac{PR/2L}{4Q/\pi R^3} \tag{2}$$

where P is the pressure; R, the radius, and L, the length of the capillary; and Q, the flow rate. In any viscometer, where R and L are constant,

$$\eta = C\frac{P}{Q} \tag{3}$$

where the constants are collected to give $C = \pi R^4/8L$.

Many materials do not flow laminarly. One such system is the ideal plastic defined by Bingham's equation,

$$\eta = \frac{F-f}{dv/dr} \tag{4}$$

in which f is called the yield value. A Bingham plastic totally resists flow as force is applied until a critical force is exceeded. Under larger forces, the flow is laminar. Applying this equation to flow in capillaries requires Buckingham's integration[6] of the Bingham equation,

$$Q = \frac{\pi R^4}{8L\eta_p}\left(P - \frac{4p}{3} + \frac{p^4}{3P^3}\right) \tag{5}$$

The limiting viscosity, η_p, and yield value, $f = \Phi(p)$, are presumed constant for any one material.

The left curve in Figure 1 shows the linear relationship obtained for Newtonian liquids. The right curve shows the typical relationship for a Bingham plastic. Buckingham's equation allows three situations as the applied force is increased: below the yield pressure, p, no flow occurs; above

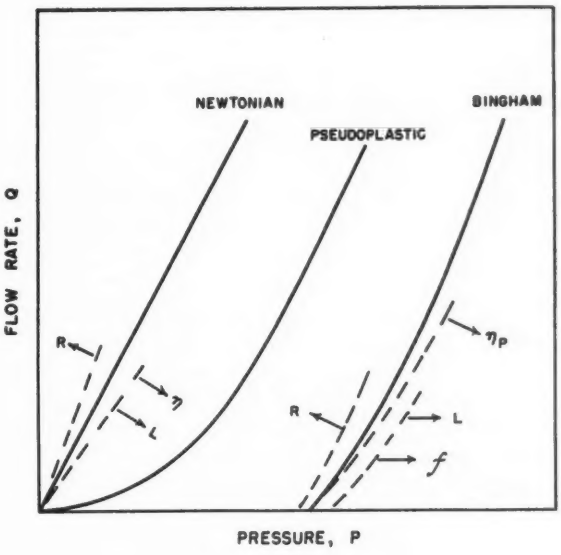


Figure 1. Types of flow.

the yield pressure but below the straight-line portion of the curve, plug and laminar flow occur; at large forces, complete laminar flow occurs. Arrows indicate the changes that occur as R, L, η, η_p and f increase.

The third system combines the characteristics of the first two. A pseudoplastic resembles a Newtonian liquid in that it exhibits no yield value and a Bingham plastic in that flow is not laminar. In this case, the relation between shear stress and shear rate may be defined by Eyring's equation:

$$dv/dr = A \sinh B\,\sigma \tag{6}$$

If the relationship between shear stress and shear rate for a pseudoplastic is logarithmic, a simple-power equation may

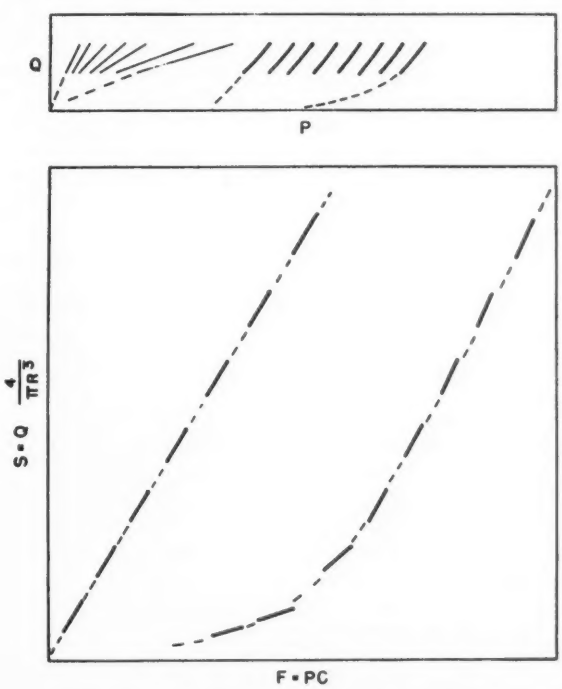


Figure 2. Comparison of P-Q and F-S curves.

approximate the flow. The equation is

$$F = KS^n, \text{ or } \log F = \log K + n \log S \qquad (7)$$

Lubricating materials differing widely in flow properties are included under the term "grease." Some flow like a Newtonian liquid and some like a pseudoplastic or possibly like a Bingham plastic. Furthermore, many greases change during flow, [23] becoming less viscous (thixotropic) or more viscous (rheopectic, dilatant), and further complicate interpretation of the nature of the flow.

METHODS

The literature reveals five mathematical ways to describe the flow of grease. If flow is assumed to be related to that of a Newtonian liquid, two ways can be used: apparent viscosity and viscosity at the wall. If flow is assumed to be more like that of a Bingham plastic, a method based on the Buckingham integration can be used. If flow is pseudoplastic, the power equation might be used. If flow is considered to be a rate process, an equation can be derived from flow data through the use of Eyring's relaxation theory for viscous flow.[10] These treatments range from the empirical to the theoretical.

Apparent Viscosity

The most common means for obtaining apparent viscosity is the ASTM method.[1] Shearing stress, F, is calculated by the equation:

$$F = PR/2L \qquad (8)$$

Because the method fixes the ratio, R/L, for all capillaries used, this equation reduces to $F = P$. Constant. Shear rate, S, is calculated by the equation for a Newtonian liquid:

$$S = Q\frac{4}{\pi R^3} \qquad (9)$$

A plot of F and S derived from P and Q is shown in Figure 2. For Newtonian liquids, the family of straight lines on the P-Q plot becomes one straight line on the F-S plot. For most greases, the P-Q curves in different capillaries are not straight lines. They appear to become a single curve on an F-S plot. The range of flow rates in the ASTM method is too narrow to reveal deviations from the average line. However, when even a wider range is used, as shown in Figure 3, the data still appear to be on a single curve. These data were obtained in capillaries of constant ratio, L/D.

The method calculates viscosity from F and S. Because F/S is not constant, the calculated number is called apparent viscosity and is represented by a locus of points on a curve of apparent viscosity, η_a, versus shear rate, S. Figure 4 shows a plot of these values for a Newtonian liquid and a typical grease.

Although several errors occur in measured pressures, the ASTM method makes no provision for correcting them. Generally recognized sources of errors are temperature effects, kinetic-energy effects, friction in the cylinder, convergence at the capillary opening, and orientation effects. Temperature corrections can only be made by analogy with Newtonian-liquid systems. Kinetic-energy corrections are usually insignificant in this viscometer. Friction, convergence, and orientation can be corrected for some greases. The magnitude of all these errors varies with each grease.

Figure 5 relates η_a to S for a grease and shows the results of correcting the data. The upper curve shows data obtained as prescribed by the ASTM method. The middle curve shows the same data corrected for convergence and friction by subtracting from the observed pressure that pressure required to force grease through 0.005-inch plates hav-

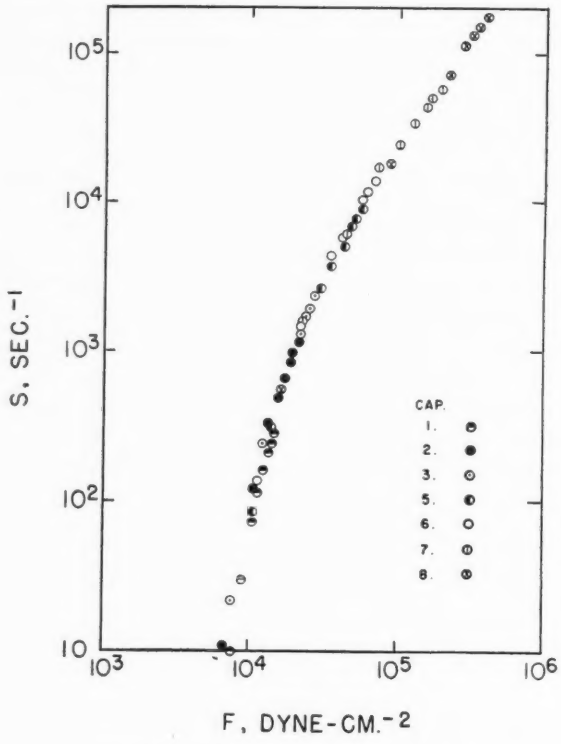


Figure 3. F-S at wide range of flow rates.

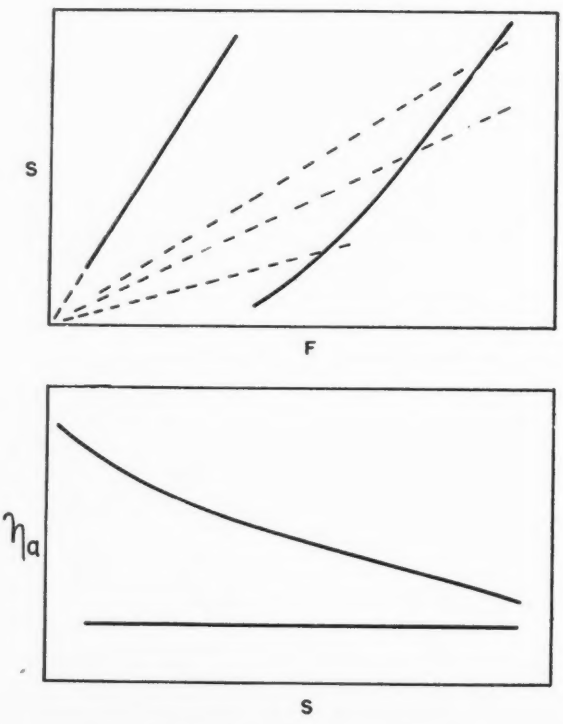


Figure 4. Calculation of apparent viscosity.

ing holes the same diameter as each capillary. The lower curve shows data corrected also for orientation by subtracting from the observed pressure that pressure obtained from a shorter capillary ($L/D = 12/1$). For a grease like that shown in Figure 5, Singleterry[21] claims that orientation occurs in 1 to 2 diameters. These corrections do not alter the shape of the η_a curve but do reduce the values of η_a. Corrected data should be used in comparing ways of interpreting grease flow.

Although the ASTM method may lead to a single, reproducible curve for a grease, F/S is by no means a proper representation of this curve. The entire spectrum of F/S values is needed to define grease flow.

Viscosity at the Wall

Another mathematical treatment, first applied to greases by Blott[4] and later by Marusov,[12] defines shear stress and shear rate at the wall. The mathematics was developed originally by Rabinowitsch,[20] and further by Mooney.[16] The equation for viscosity at the wall, η_w, is:

$$\eta_w = F/S_w \tag{10}$$

where, by analogy with Poiseuille's equation, shear rate at the wall, S_w, is $3Q/\pi R^3 + F\, d(Q/\pi R^3)/dF$.

The method of calculation outlines the three steps shown graphically in Figure 6.

1. Plot flow rate, Q, versus shear stress, $F(=PR/2L)$, and determine the slope, dQ/dF.
2. Plot shear rate at the wall, S_w, versus F.
3. Determine viscosity at the wall, η_w, and plot versus S_w.

To compare η_w with η_a, published data from three sources were used, as shown in Figure 7. Curve A is from Arveson;[2] the points are recalculated from his data to get values for η_w. Curve B is the η_a curve calculated from the data of Blott.[4] Curve C is the η_a curve calculated from the data of Marusov.[12] The coincidence of these points and curves show the close resemblance between η_w and η_a.

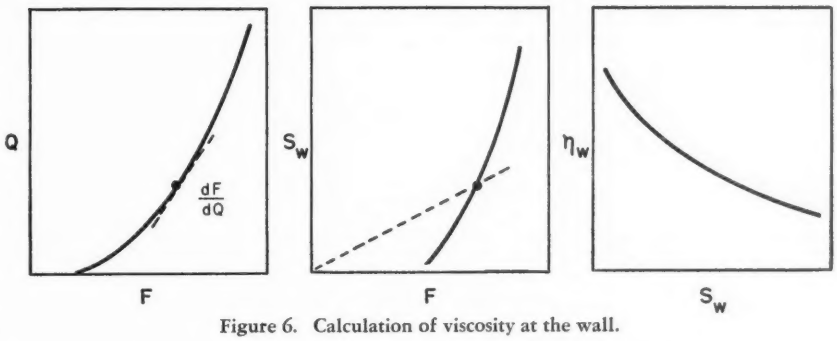


Figure 6. Calculation of viscosity at the wall.

Buckingham Equation

Buckingham's equation may be written

$$Q = \frac{\pi R^4 m}{8L}\left(P - \frac{4p}{3} + \frac{p^4}{3P^3}\right) \tag{11}$$

where m is the mobility ($= 1/\eta_p$). Caldwell and Babbitt[7] reduced the quantity in parentheses to a dimensionless term that is a function only of the relative extent of plug flow:

$$Q = \frac{\pi R^4 m P}{8L}\left(1 - \frac{4p}{3P} + \frac{p^4}{3P^4}\right) \tag{12}$$

McMillen[14] solved the equation in terms of two dimensionless quantities:

$$c = b/R$$

$$a = \frac{c^4 - 4c + 3}{12c} \tag{13}$$

where b is the radius of the unsheared plug. He reduced these equations to graphs of dimensionless constants that make solution possible. The McMillen equations for the calculation are:

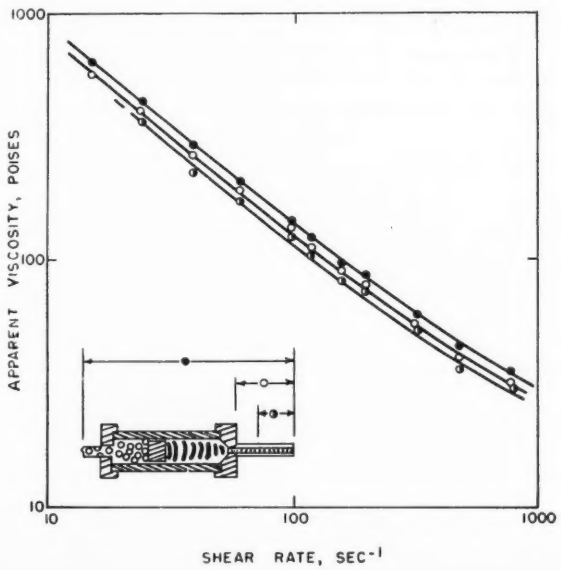


Figure 5. Apparent-viscosity corrections.

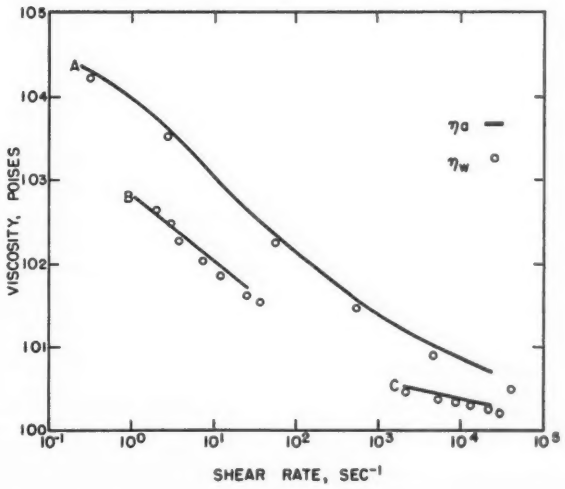


Figure 7. Comparison of apparent-viscosity and viscosity at the wall.

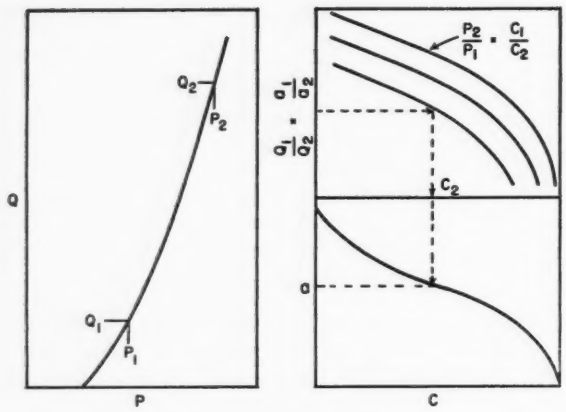


Figure 8. Calculation of Buckingham constants.

$$f = PRc/2L$$

$$m = Q/\pi R^3 fa$$

$$\eta_p = 1/m = (P/Q)\frac{\pi R^4 ca}{2L} \qquad (14)$$

Singleterry and Stone[21] made further use of graphs and applied the McMillen equations to greases.

Calculation of f and m by means of the Buckingham equation involves 6 steps outlined in Figure 8.

1. Plot flow rate, Q, in one capillary, versus pressure, P.
2. Select a ratio $P_2/P_1 (= c_1/c_2)$, using the largest experimental range possible.
3. Read corresponding values for Q_1 and Q_2 from the P-Q plot.
4. Determine c_2 from a plot of a_1/a_2 $(= Q_1/Q_2)$ versus c_2.
5. Determine a_1 and a_2 from c_1 and c_2 by a plot of a versus c.
6. Calculate f and m from the McMillen equations.

The curve for the Buckingham equation can then be determined.

Applications of the McMillen equations to grease have been made. Singleterry, [21] using only one capillary, found good agreement between P-Q data and the Buckingham equation. P-Q data on three greases were obtained from an ASTM viscometer by the authors. Pressures were corrected. Calculations of f and m were made for each grease from data from four capillaries. The results are shown in Table I. Grease A is similar to that used by Singleterry. The values for f were nearly constant for greases A and B but not for C. In all greases, the values of η_p were not constant. An attempt was made to apply the Buckingham equation constants obtained from one capillary to the calculation of the Buckingham line for a capillary of different radius. In Figure 9 the dotted line, "c," represents the

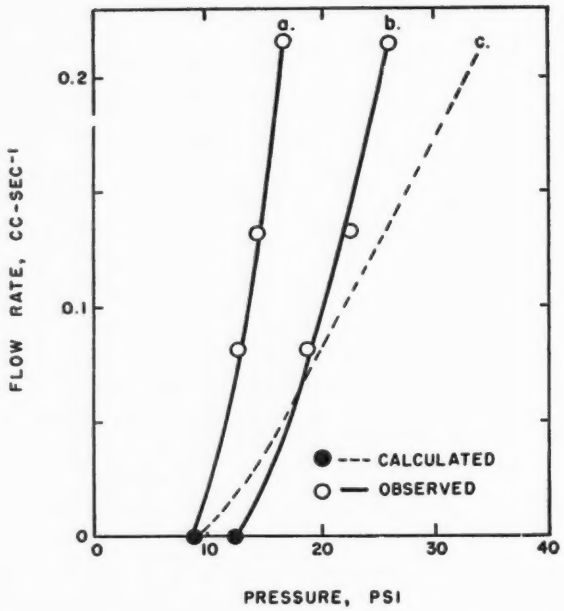


Figure 9. Comparison of flow data with Buckingham equation.

Buckingham equation calculated from the data of capillary "a" which should correspond to line "b." Although these greases appear to have flow curves resembling the P-Q curves for Bingham plastics, they may actually demand mathematics that are more complex.

Eyring Equation

As early as 1944, Powell and Eyring[19] showed that flow of grease can be expressed by the equation:

$$\sigma = \mu\left(\frac{dv}{dr}\right) + \frac{1}{B}\sinh^{-1}\left(\frac{1}{A}\frac{dv}{dr}\right) \qquad (15)$$

In rotational viscometers the shear stress (σ) and rates (dv/dr) are known, and the unknown constants μ, B, and A may be calculated from three points on the stress-shear rate curve.

Christiansen, Ryan, and Stevens[8] have applied the equation to pipe data on some pseudoplastics other than grease, but the calculations are less direct. The three characteristic constants μ, B, and A are combined in the dimensionless equations:

$$a = \Phi(\beta)\ (\gamma) \qquad (16)$$

where,

$$a = Q/AR^3$$

$$\beta = BPR/2L$$

$$\gamma = AB\mu$$

Table I
Yield Value & Limiting Viscosity at 77° F.

Grease	A		B		C	
Oil Vis., SSU 100°F.	70		300		800	
NLGI Grade	0		2		1.5	
ASTM Capillary	f dyne/cm²	η_p poises	f dyne/cm²	η_p poises	f dyne/cm²	η_p poises
1	5400	22	8600	—	3800	62
2	—	—	8100	21	5400	27
3	—	—	9100	15	5400	22
5	6900	3	8900	13	10,000	7

The graphical solution of $a = \Phi(\beta)$ (γ) is shown in Figure 10.

Experimental values for P and Q are handled in the following manner:

1. Plot $Aa = Q/R^3$ versus $\beta/B = PR/2L$.
2. Superimpose on Figure 10; read a and β on the lower plot, *Aa and* β/B on the upper.
3. Calculate the constants A, B, μ.

By such calculations, Christiansen et al predicted flow in pipes of one size from data from pipes of smaller size on materials similar to grease.

The work of Christiansen shows the possibility of predicting the flow of grease in pipes from capillary flow data. Independent of this possibility, the Powell-Eyring equation might be used for characterizing the shear stress-shear rate curves obtained from capillary viscometry. Three values (solid circles in Figure 11) of $4Q/R^3$ and $PR/2L$ were used to calculate the constants A, B and μ from the Powell-Eyring equation. Just how well this equation fits all of the data for a typical grease is shown in Figure 11. It remains to be demonstrated whether or not capillary data may be used to predict flow in pipes.

Power Equation

Flow of pseudoplastics may also be approximated[8, 15, 22] by some form of the power equation:

$$F = KS^n \qquad (17)$$

It has not been determined if grease can be handled in this manner, but Figure 11 shows that the power equation does not fit a typical grease any too well, because $\log F = n \log S + \log K$ approximates this curve by a straight line.

DISCUSSION

Regardless of the mathematics applied, flow-pressure data are needed to solve four kinds of problems: specifying greases for a particular problem in lubrication; empirically correlating flow in capillaries and in practice; calculating pressures and flow rates under specified conditions; and understanding grease structure. To determine if a method is suitable for any or all of these needs, three tests must be applied: Does the mathematics fit the flow-pressure relationship? Are the capillary data sufficiently general to allow mathematical translation to some other system? Does the mathematics provide parameters that allow basic as well as practical conclusions?

Apparent viscosity or viscosity at the wall can hardly be described as fitting the data because they only translate the data to a curve. Dividing F by S results in a variable that is merely a convenient restatement of the flow-pressure relationship in a given system. These methods are suitable for specification purposes, provided the viscometer conditions are rigidly observed. Furthermore, because the result is a variable, specifications must be either based on a wide range of shear rate or considered as applying to a limited range of service. Empirical correlations with practice may be made by comparing the apparent viscosity of greases at shear rates that approximate the service condition. Although η_a is related to thickener concentration at low shear rate and to oil viscosity at high shear rate, and changes in η_a are related to thixotropy, no more-basic conclusions about structure are possible.

To the extent that greases obey the Buckingham equation, McMillen's technique provides two constants that should be convenient for specifications. The constants f and m may be regarded as roughly related to thickener concentration and oil viscosity, respectively. Correlations with service should be possible. There is no evidence that flow of grease in pipes can be predicted from capillary measurements by this method. Hedstrom used dimensionless terms containing f and m to predict the flow of plastic systems. He contends that rotational-viscometer data are required even for systems that obey the Buckingham equation.

In applying the power equation, K and n might be used for specifications, and the plot of friction factor versus modified Reynolds number might be used to calculate pipe flow if Figure 11 were a straight line. On the basis of the typical grease used, the power equation appears to be only a fair approximation. Relating larger capillaries to pipe flow looks possible but has not been tried. Metzner and Reed[15] used capillary data to evaluate K and n for systems similar to grease. They calculated flow in pipes by means of a special Fanning friction factor and Reynolds number.

The Powell-Eyring equation appears to be the most

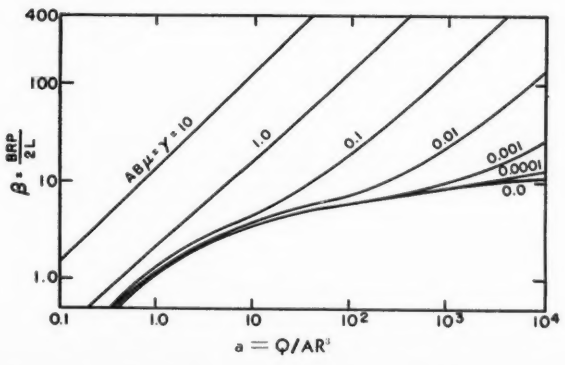


Figure 10. Graphical solution of the Powell-Eyring equation.

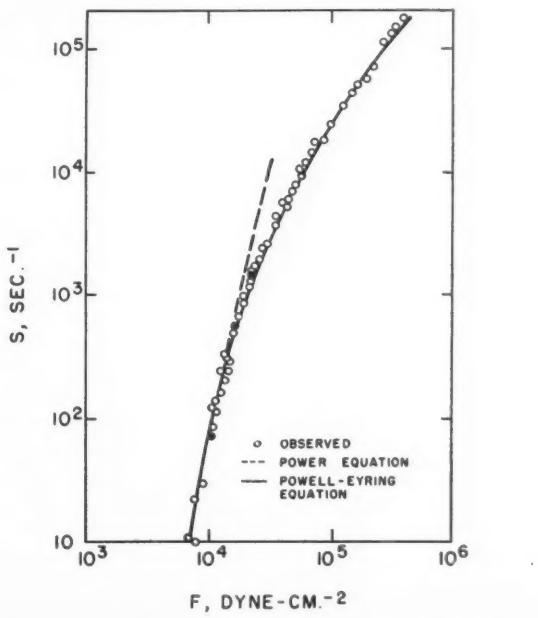


Figure 11. Application of Powell-Eyring and power equations to F vs. S data.

versatile method of handling grease flow. The three constants A, B, and μ might be used for specifications. Calculations of flow in 1½ inch pipe have been made successfully from measurements in ⅞ inch tubes for materials similar to grease. It remains to be shown if capillaries can also be used. The equation does handle *F-S* capillary data for greases. Powell-Eyring constants have a good chance of relating to structure parameters.

As yet, no method has proved suitable for all four problems. The Powell-Eyring equation holds the most promise. It will be necessary to demonstrate that grease flow in capillaries can be used to predict pressure losses in pipe lines. Also, there remains a need to relate flow to structure parameters of grease. The Eyring approach justifies further study.

BIBLIOGRAPHY

1. American Society for Testing Materials, "Standards on Petroleum Products and Lubricants," D1092-51, 1954.
2. Arveson, M. H., *Ind. Eng. Chem., 24*, 71 (1932); ibid., *26*, 628 (1934).
3. Beerbower, A., Sproule, L. W., Patberg, J. B., and Zimmer, J. C., *Inst. Spokesman, 6*, No. 8, 9 (1943); ibid., 6, No. 11, 11 (1943).
4. Blott, J. F. T., and Samuel, D. L., *Ind. Eng. Chem., 32*, No. 1, 68 (1940).
5. Brunstrum, L. C., and Steinbruch, R., *Inst. Spokesman, 13*, No. 8, 10 (1949).
6. Buckingham, E., *Am. Soc. Testing Materials, Proc., 21*, 1154 (1921).
7. Caldwell, D. H., and Babbitt, H. E., *Ind, Eng. Chem., 33*, 239 (1941).
8. Christiansen, E. B., Ryan, N. W., and Stevens, W. E., *A.I.Ch.E. Journal, 1*, No. 4, 544 (1955).
9. Dreher, J. L., Carter, C. F., and Reid, E. B., *Inst. Spokesman, 18*, No. 10, 8 (1955).
10. Eyring, H., and Ree, T., *Appl. Phys., 26*, No. 7, 793; 800 (1955).
11. Hedstrom, B. O. A., *Ind. Eng. Chem., 44*, No. 3, 651 (1952).
12. Marusov, N., *Inst. Spokesman, 15*, No. 5, 8 (1951).
13. Marusov, N., *Inst. Spokesman, 19*, No. 6, 10 (1955).
14. McMillen, E. L., *Chem. Eng. Progress, 44*, 537 (1948).
15. Metzner, A. B., and Reed, J. C., *A.I.Ch.E. Journal, 1*, No. 4, 434 (1955).
16. Mooney, M., *J. Rheology, 2*, 210, (1931).
17. Pigott, R. J. S., *Inst. Spokesman, 11*, No. 9, 4 (1947).
18. Poiseuille, J. L. M., *Comptes rendus, 15*, 1167 (1842).
19. Powell, R. E. and Eyring, H., *Nature, 154*, 429 (1944).
20. Rabinowitsch, B., *Z Physik. Chem., A145*, 1 (1929).
21. Singleterry, C. R., and Stone, E. E., *J. Colloid Sci., 6*, No. 2, 171 (1951).
22. Weltmann, R. N., *Nat. Advisory Comm. Aeronaut., Tech. Notes*, 3397, (1955).
23. Wilson, J. H., and Smith, G. H., *Ind. Eng. Chem., 41*, 770 (1949).

Current Literature

Ratchet-Drive Lubricator. A 2-page technical reference sheet is available that describes an automatic ratchet-driven lubricator, designated Type NV, designed for servicing small machines and mechanisms where installation space is limited and where an oscillating drive is more readily available than rotary motion. The reference describes in detail the key features of the lubricator, such as: pump cycle, different gear reductions available, reservoir, ratchet-drive mechanism, and instant feed button. Accompanying a diagram illustrating the lubricator's operation, is a table listing ratchet arm working angles, and reduction ratios for three different models available—the NVF, NVH, and NVL. (Sheet No. 55B, Bijur Lubricating Corp. ,LE-12/5, 151 W. Passaic, Rochelle Park, N. J.)

Metalworking Catalog. Most effective cutting speeds for carbide tools, machine tool horsepower requirements, how to determine shank size of single-point tools, carbide tool geometries, carbide grade selection, and other technical topics, are covered in a new 66-page metalworking catalog recently issued. Besides information on the Carboloy machinability computer, the new 2-color publication also includes price and specification information on standard brazed carbide tools, tool holders, standard carbide throwaway inserts, blanks for twist drills, dies, bushings, guide rings, balls, valve seats, and many other applications. (Catalog No. GT-310, Carboloy Dept., General Electric Co., LE-12/5, Detroit 32, Mich.)

Moisture-Analysis Equipment. Of interest to chemists, chemical engineers, physicists, and others engaged in research, analysis, and control, is a new catalog providing a complete list of the latest equipment for determining moisture in a great variety of materials. The catalog illustrates and describes every item needed for accurately analyzing the amount of moisture in any solid, granular, liquid, or semi-liquid material; listed are Dietert moisture tellers, speed ovens, speed desiccators, and accessory items such as balances, weights, sample pans, and drying dishes. (Harry W. Dietert Co., LE-12/5, 9330 Roselawn Ave., Detroit 4, Mich.)

"The 1956 Guide to Approved Lubrication for Passenger Cars & Light Trucks," among its 160 pages of lubrication charts, service instructions, and tabular data, introduces two tabular pages of lubricant recommendations for the most popular European passenger cars in use today. In the expected full coverage, all 1956 model requirements are presented; with service data for older models revised to reflect any changes manufacturers have made in their lubricant and service specifications. The most popular light trucks are incorporated as well, with further special service instructions and marketing pages related to lubrication and accessories. (For prices, write: The Chek-Chart Corp., LE-12/5, 33 E. Congress Pkwy., Chicago 5, Ill.)

Vacuum Distillation Unit. A new leaflet is offered that covers a specialized apparatus produced to meet the requirements of reduced pressure distillations of pe-

(Continued on p. 337)

The Place for Emulsions as Fire-Resistant Power Transmission Fluids

A water-in-oil emulsion has been developed to fulfill the need for a low-cost, fire-resistant industrial hydraulic fluid. Its resistance to ignition has been satisfactory in industrial operations, and laboratory and field studies have shown it to be suitable as a hydraulic fluid in other respects. This paper discusses the characteristics and performance of this fluid.

G. T. Coker, Jr. & C. E. Francis
Shell Oil Company
Martinez, Calif.

The increasing use of hydraulically-powered industrial equipment in operations where a potential source of ignition exists, as in die casting machines, automatic electric welders and furnace door actuators, has accentuated the need for fire-resistant hydraulic fluids. These fluids decrease the hazards to both personnel and plant sufficiently that a reduction in insurance premiums is warranted. A number of fire-resistant fluids have been in commercial use, each having certain unique characteristics. These include degree of flammability, performance with respect to both temperature and pressure, effect on paints, seals, packings and hoses, maintenance of fluid quality, compatibility with other types of fluids, and cost.

Perhaps the most direct way to obtain a fire-resistant hydraulic fluid is to synthesize a non-flammable compound having suitable lubricating characteristics and physical properties. Fluids based on organic phosphates are the most widely known of this type, and considerable industrial experience has been gained on their performance. The phosphate esters now used are flame resistant to a high degree and match mineral oil in lubricating quality. They have a very low viscosity index, and attack some of the sealing and paint materials which have been commonly used with mineral oil. Cost is high.

The other common approach to the development of a fire-resistant fluid is to utilize the fire-quenching properties of water, and this may be done in any of three ways. First, the water, which in itself is not a good enough lubricant for hydraulic pumps, may be thickened to the necessary degree with high concentrations of materials such as the polyalkylene glycols. Several such products have received commercial acceptance. The fire-quenching effect of these materials is very good as they can contain about 50 percent water. Modifications to seals and protective paints may be required for their use in some cases, and the lubricating property may not be as uniformly good as that of mineral oil. Cost has been below that of the esters. By another approach, some degree of lubricity may be imparted to water by dispersing oil throughout the water; that is, by making the normal oil-in-water type of emulsion. These have been widely used where lubrication is not critical, but they are inadequate for lubricating the highly loaded contacts found in many pumps as fluid pressures approach 1000 psi. Of the methods of utilizing the quenching properties of water, probably the most attractive is the use of an emulsion in which the oil is the continuous phase. Such a fluid is the subject of this paper. It has been found that this water-in-oil type of emulsion does not suffer from the lubricating deficiency of normal emulsions, yet it retains the fire resistance which is derived from the water content. Such materials have a definite place in the lubrication of industrial hydraulic systems in hazardous locations.

This paper was presented at the ASLE 11th Annual Meeting, Pittsburgh, April 5, 1956.

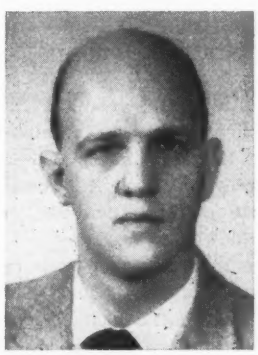
FORMULATION

In the preparation of a water-in-oil emulsion type fluid, fire resistance is of course enhanced by increasing the water content. This improves emulsion stability, but it also markedly increases viscosity. The relationship between water content and viscosity is illustrated by the curve for water-in-oil emulsion in Figure 1. A satisfactory balance of fire resistance, viscosity, and emulsion stability was obtained by emulsifying an oil of suitable viscosity to give a final emulsion containing 40 wt. % of water. A choice of emulsifiers was made only after the study of several thousand combinations; it was based on avoiding water separation and on obtaining the minimum amount of oil separation during storage. On the basis of early experience, which indicated that oxidation of these emulsions was a critical problem, a high degree of oxidation-resistance was provided in the final product.

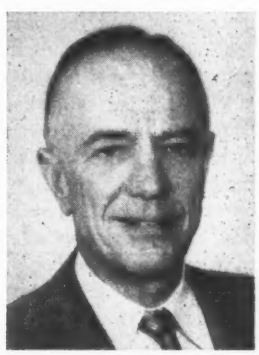
CHARACTERISTICS

Fire Resistance

The function of the emulsion in reducing the hazard of fire is that of producing a steam blanket at those temperatures which would usually result in the ignition of a conventional fluid. As with other water base fluids, the



G. T. Coker, Jr.



C. E. Francis

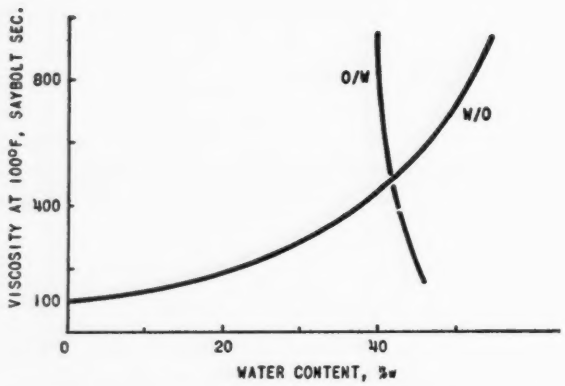


Figure 1. Effect of water content on viscosity of oil-in-water and water-in-oil emulsions prepared from 100 SSU at 100° F. MVI mineral oil.

complete loss of water from the emulsion leaves an ignitable residue. In practical situations where there is a potential fire hazard, however, the formation of steam and the concurrent loss of oil by vaporization greatly reduces the hazard or eliminates it entirely.

Since the fire resistant requirements of hydraulic fluids vary with the type of service, there have been a multitude of tests developed for its evaluation. These include spontaneous ignition tests; a "Hot Manifold" test,[1] in which the fluid is poured on a steel tube heated to 1300° F.; a "High-Temperature Spray" test,[1] wherein an attempt is made to ignite a jet of the fluid with an oxy-acetylene flame; and a "Pipe Cleaner" test[2], in which a smoking-pipe cleaner saturated with the fluid is passed between grids heated to 1400° F. The water-in-oil emulsion has been examined in a number of these tests, and the results in all cases have been indicative of satisfactory fire resistance. One comparison of the flammabilities of the emulsion and mineral oil is shown in Figures 2 and 3. In this test, the fluids were sprayed with an air aspirator across the flame from a laboratory gas burner.

The fire resistance of this type of emulsion has been dramatically demonstrated by field experience. During one of the earliest field trials with the emulsion, a swivel joint failed in a new 400 ton die casting machine shortly after the machine was placed in operation on the emulsion. Approximately ten gallons of fluid drained directly into a pot of molten zinc alloy. The water released by vaporization formed a protective steam blanket. After several minutes a small luminous flame appeared in the melting pot, but there was no damage or lost time. The leak was repaired temporarily, and the unit operated ten hours with some continued leakage onto the molten metal. There was no flame during this period.

In another shop, a one-half inch nipple on the accumulator of a die casting machine broke, and approximately ten gallons of the fluid at 1000 psi sprayed against the ceiling and then dripped back on two machines, several operators, and two aluminum melting pots. There was no flash or fire, and only a brief shutdown was necessary.

In a third die casting plant, a cracked high-pressure fitting on a hydraulic power unit resulted in a fine mist of fluid spraying into the air in the general vicinity of a melting furnace. Although the mist drifted into the flame, there was no flashback or burning outside the furnace. These and other similar incidents have engendered strong confidence in the safety of the emulsion.

Stability

As mentioned in the section on formulation, the emulsion has been compounded so that water separation during normal storage is avoided. Samples have been stored as long as one year without showing water separation. Some separation of oil does occur, the degree depending upon the temperature and duration of storage. For example, after 35 days storage at normal temperatures, the emulsion developed a clear oil layer amounting to about 5 vol. % of the emulsion and a layer of "oily cream" of about 30 vol. %. Experience has shown that such an emulsion can easily be re-mixed with moderate agitation. These emulsions do not separate on freezing, although laboratory studies show that repeated wide temperature variations of 50 to 100° F. can have an adverse effect on stability. With a different choice of emulsifiers, similar emulsions can be prepared which show greatly improved stability against oil separation, but it appears that they do not as readily re-emulsify water which evaporates from the emulsion and condenses in the reservoir of an operating system.

Viscosity

Figure 4 shows that the emulsion-type fluid, as cur-

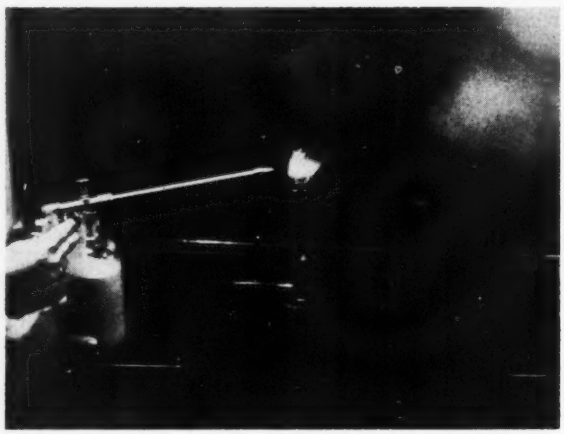


Figure 2. Flammability test (low-pressure spray) on emulsion-type hydraulic fluid.

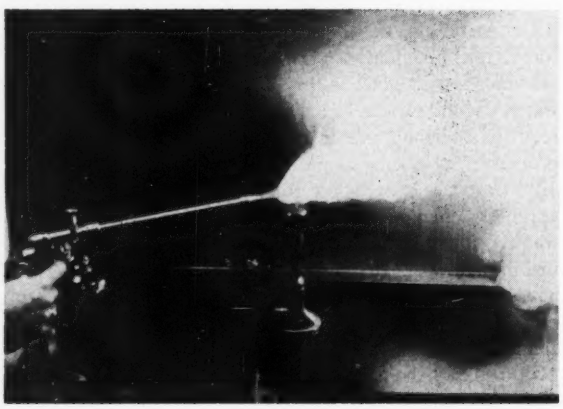


Figure 3. Flammability test (low-pressure spray) on mineral oil.

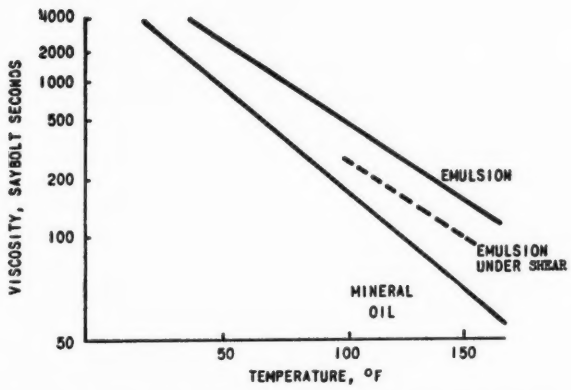


Figure 4. Effect of temperature on viscosity of mineral oil and the water-in-oil emulsion at very low shear rates and at 10,000 sec^{-1}.

rently formulated, has a viscosity of approximately 450 SSU at 100° F. This is considerably higher than the range of 150-300 SSU at 100° F. generally recommended by pump manufacturers. However, since the emulsions are non-Newtonian fluids, the effect of shear on viscosity must be considered in arriving at the operating viscosity in a hydraulic pump and its associated mechanisms. Viscosity determinations of the emulsion under shear rates up to 200,000 sec^{-1} have shown that the viscosity decreases rapidly as the shear rate is increased to about 1000 sec^{-1}, above which it remains nearly constant at a value of approximately 250 SSU at 100° F. Confirmation that this reduction of viscosity is real has been afforded by laboratory tests on the emulsion and on mineral oil in the same pump at identical conditions of speed, pressure, and temperature. No significant differences were observed in power input, heat output, or flow rate. The viscosity index of the emulsion is about 130 and apparently is independent of shear rate. The higher viscosity of the emulsion at a low shear rate requires that special attention be given to pump suction conditions. To avoid pump starvation and cavitation, suction lines must be as short and as direct as possible, and the suction screen capacity should be at least three to four times the rated pump capacity. It has been feasible in some instances to remove the screens entirely.

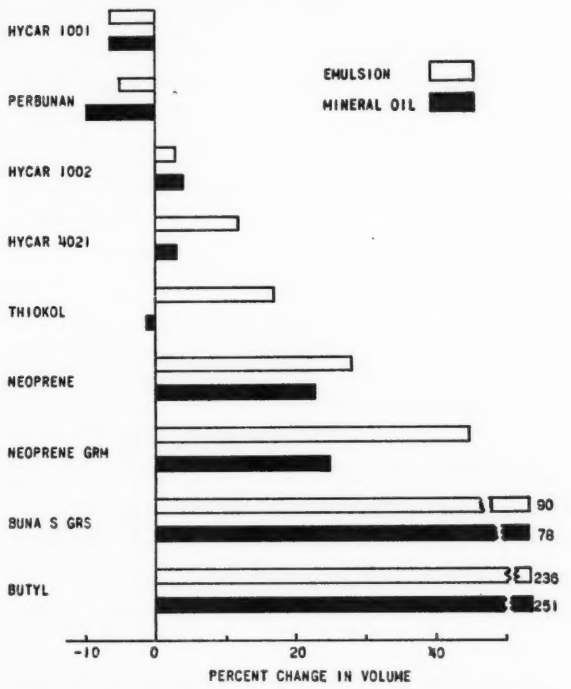


Figure 5. Effect of emulsion-type hydraulic fluid and mineral oil on synthetic rubbers (one week immersion at 160° F.).

Effect on Seals and Paints

Almost without exception, industrial hydraulic equipment is manufactured for use with mineral-base hydraulic oils, and the paints, seals, gaskets, packings, and hoses are selected accordingly. As it was known that such material can be adversely affected by other types of fluids, the emulsion was carefully examined in this regard. The relative tendencies of the emulsion and mineral oil to swell a wide variety of synthetic rubbers are shown in Figure 5. These results are in accord with service experience, which shows that there is no adverse effect of emulsion in a system fitted with seals, etc., designed for mineral oil service. With regard to paint removal, there has been no difficulty in service, although laboratory immersion tests at 160° F. indicate that certain paints may be softened at elevated temperatures. This is probably of little practical importance, in view of the trend toward unpainted sump interiors in industrial systems.

Rusting and Corrosion

While one might expect light rust to form on the unpainted interior surfaces of the sump above the fluid level, rusting has not been a problem either in laboratory or field tests. Steel and copper panels in contact with one another and immersed in the emulsion for one week at 160° F. have shown no loss in weight. Steel, copper, magnesium, and aluminum panels in a similar test where the metals were not in contact also showed neglible weight losses, although staining of the copper and magnesium was noted.

Foaming and Air Entrainment

No difficulty has been encountered with foaming or air entrainment with the emulsion in the laboratory pump tests, nor has any been reported in the field tests.

Performance in Hydraulic Systems

(1) *Laboratory Tests* — The performance of the emulsion has been studied in numerous laboratory tests utilizing both vane and piston pumps. Most of the work was done with a single stage 5 gpm vane pump mounted on a 30 gallon reservoir. The fluid was pumped through a pressure control valve and returned to the sump. The temperature of the fluid at the pump inlet was controlled at 150° F., pump speed at 1200 rpm, and pump discharge pressure at 1000 psi. Samples of the fluid were taken daily and examined for viscosity and water content. Pump wear was measured by weighing the individual parts, i.e., vanes, ring, rotor, and port plates, at intervals during the test.

Typical performance data comparing the water-in-oil emulsion with an oil-in-water emulsion and a conventional mineral oil are shown in Table I. Very high wear of pump parts and a marked increase in viscosity were obtained with the oil-in-water emulsion. Wear with the water-in-oil emulsion, however, was comparable to that obtained with

Table I

Performance of Fluids in Vane-Type Hydraulic Pump.[a]

Fluid	Viscosity, SSU/100° F.		Ring & Vane Wt. Loss, G.	
	Initial	Final	1200 RPM	1800 RPM
Mineral Oil	156	156	0.32	0.29
Water-in-Oil Emulsion	408	384	0.24	0.52
Oil-in-Water Emulsion	155	385	6.62	

[a]Test Conditions include: temperature, 150° F.; pressure, 1000 psi; duration, 200 hr.

the mineral oil, and the viscosity of the emulsion changed only slightly. The effect of water loss on viscosity of the two emulsion types is shown in Figure 1. This shows that for the water-in-oil emulsions, water content is much less critical, and water loss in service causes a decrease in viscosity instead of an increase. In addition to these tests, a brief study was made of the effect of operating a vane pump on the emulsion at 1800 rpm, with the other conditions unchanged. No differences were observed with respect to emulsion properties, but pump wear was twice as high as with mineral oil.

The performance of the emulsion has also been compared with that of mineral oil in an axial piston pump in which the reaction of the pistons is taken in sliding against a cam plate. Fluid temperature at the pump suction was maintained at 150° F., pump speed at 1800 rpm, and the discharge pressure at 3000 psi. No adverse change was noted in the characteristics of the emulsion after being subjected to the 3000 psi pressure. Wear was not excessive, although it was greater than that obtained in this pump with mineral oil.

(2) *Field Tests* — The emulsion has given satisfactory performance for thousands of hours in numerous field tests. These have included operation in die casting and plastic molding machines, automatic electric welders, and decoilers. With one exception, pumps have been vane-type operating, as a rule, at a maximum of 1000 psi, although in two instances pressures of 1400 and 1800 psi were developed. One radial piston pump was operated at 1800 psi on the emulsion, with satisfactory results. The knowledge obtained from these tests has shown that the pump suction-side capacity must be increased for the emulsion; and that pressure-side filters should be of moderate porosity, such as metal edge or fine mesh type (200 mesh), since filters of too low porosity are detrimental to emulsion stability. Further, the incompatibility of the emulsion with other fire-resistant fluids requires that systems which have been operated previously on the latter be adequately flushed.

SUMMARY

A relatively low-cost water-in-oil emulsion has been developed which markedly reduces the hazards from fire as compared to conventional oils, and is suitable for transmitting hydraulic power in many applications. As with all new developments, the need for improvement in certain properties has been observed and corrections have been made. A wide field of usefulness is foreseen for emulsions of the type described.

BIBLIOGRAPHY

1. Military Specification MIL-F-7100, "Fluid, Hydraulic, Non-flammable Aircraft."
2. Watson, F. J., "Small-Scale Laboratory Evaluation Tests on Synthetic Lubricants," *Lubrication Engineering*, Nov. 1955, p. 86.

Section News

Notice to ASLE Section Secretaries: To insure early and adequate coverage of your Section's activities in "Lubrication Engineering," all Section News copy (including preprints or abstracts of papers presented, Election of Officers, photographs properly identified, etc.) should be received by the ASLE National Office 1½ months prior to the month of publication.

NEW YORK. Meeting dates for the 1956-57 meetings of the ASLE New York Section will be: Oct. 11, Nov. 15, and Dec. 11, 1956; Jan. 9, Feb. 14, March 12, and May 8, 1957. All meetings will be held at Schrafft's, 556 Fifth Ave., New York City. (Submitted by M. M. Gurgo, Sec'y.)

PITTSBURGH, May meeting. R. J. S. Pigott, Gulf Oil Corp. (retired), presented a paper entitled "Some Thoughts on Bearings;" followed by Election of Officers (see ASLE Directory). Newly-elected Committee Chairmen include: W. O. Murray (Parker Appliance Co.), Entertainment; A. J. DeArdo (Aluminum Co. of America), Publicity; J. Lynch (U. S. Steel Corp.), Membership; and R. J. Sarraf (Rockwell Mfg. Co.), Finance. (Submitted by S. W. Settle.)

SAGINAW VALLEY, October meeting. Plant Tour of the Dow Corning Corp., Midland, Mich., with R. P. Schreiber, Technical Representative, as speaker.

December 6, "What Do Additives Accomplish?" by A. O. Willey, Lubrizol Corp.

January 31, 1957, Ladies Night. (Submitted by J. A. Norton, Sec'y.)

Coming Events

OCTOBER, 11 & 12, The Quartermaster Association (Industrial Seminar on Petroleum & Petroleum Products), Mayflower Hotel, Washington, D .C.

15-19, American Society of Civil Engineers (Convention), Pittsburgh, Pa.

22-24, National Lubricating Grease Institute (Annual Meeting), Edgewater Beach Hotel, Chicago, Ill.

APRIL 15-16-17, 1957, American Society of Lubrication Engineers (12th Annual Meeting & Exhibit), Sheraton-Cadillac Hotel, Detroit, Mich.

Effect of Oxygen Concentration in Atmosphere on Oil Lubrication of High-Temperature Ball Bearings

Studies were made of ball bearings operating at bearing temperatures to 850° F. and lubricated with grade 1010 turbine oil with ambient atmosphere consisting of air-nitrogen mixtures of various ratios. The results show that a 20-mm-bore ball bearing will run at temperatures to 850° F. with oil lubrication if the oil flow exceeds a critical amount, believed to be equal to that which is removed by evaporation, thermal decomposition, and oxidation. Oxidation of the oil was controlled by regulating the amounts of oxygen and nitrogen in the atmosphere surrounding the test bearing.

Z. N. Nemeth & W. J. Anderson
NACA, Lewis Flight Propulsion Laboratory
21000 Brookpark Rd.
Cleveland 11, Ohio

INTRODUCTION

The trend toward higher bearing temperatures in turbojet engines[1-4] emphasizes the need for more research on high-temperature bearing lubrication. There are several approaches to the problem, including (a) the use of closed lubrication systems,[5] (b) the use of solid lubricants,[6-9] or (c) the use of air-lubricated hydrostatic bearings.[10] Solid lubricants have been found to be effective high-temperature lubricants, but they must be evaluated in full-scale engine-bearing tests before their value can be gaged accurately. Although the use of air-lubricated hydrostatic bearings would be advantageous, a number of problems would be associated with their use and these problems have not been solved yet.

Experiments with the solid-lubricant molybdenum disulfide (MoS_2)[9] led to the use of a nitrogen atmosphere to extend the limiting temperature of this lubricant. In the presence of air, MoS_2 begins to oxidize above 750° F.[11] producing an abrasive oxidation product. Its effectiveness as a lubricant was found to be closely related to its oxidation characteristics. With oxygen available, MoS_2 was not effective as a lubricant at temperatures much above 700° F.,[9] but in a nitrogen atmosphere it was effective at 1000° F. These findings led to the use of a nitrogen atmosphere with liquid lubricants and, here too, it was found that the limiting temperatures for liquid lubricants could be extended by excluding oxygen from the atmosphere surrounding the bearing.[9] Sorem and Cattaneo found that the removal of oxygen from the environment of the bearing extended bearing life at 600° F. when lubricated with hydrocarbon vapor.[12]

The logical question arising from the foregoing experiments was how much oxygen, if any, could be tolerated if effective lubrication were to be maintained. This investigation was conducted to determine the relation between available oxygen and the effectiveness of lubrication.

Presented under the sponsorship of the American Society of Lubrication Engineers before the Second Annual ASLE-ASME Lubrication Conference, Indianapolis, Ind., October 10-12, 1955.

The investigation was conducted at the NACA Lewis laboratory, Cleveland, Ohio.

TEST EQUIPMENT

The bearing rig, Figure 1, was constructed around a floor-type drill press and is described in detail in Reference 8. The test-bearing housing was supported on an externally pressurized thrust bearing and was restrained from moving circumferentially by a strain-gage assembly which measured friction force. A resistance furnace surrounded the test-bearing housing. Load was applied by means of a lever and dead-weight system which applied load in the axial direction. Outer-race and inner-race temperatures were obtained by thermocouples in the housing and on the shaft.

Test bearings were size 204, 18-4-1 tool-steel ball bearings equipped with two-piece stamped and riveted silver-plated beryllium-copper cages.

In all tests the bearings were lubricated with MIL-L-6081A, grade 1010 oil introduced in droplet form. The lubricant had a viscosity of 40,000 centistokes at —65° F. and 2.47 centistokes at 210° F., and was introduced to the test-bearing cavity at room temperature.

The flow rate of lubricant was 0.0002 to 0.001 lb per min (15 to 52 drops/min). Full details of the lubricant supply system are given in Reference 8.

The air and the nitrogen were metered by calibrated lengths of capillary tubes. The proportion by volume of each gas was varied to give the desired oxygen concentration, the total gas flow being kept constant at 0.12 cfm.

Z. N. Nemeth

W. J. Anderson

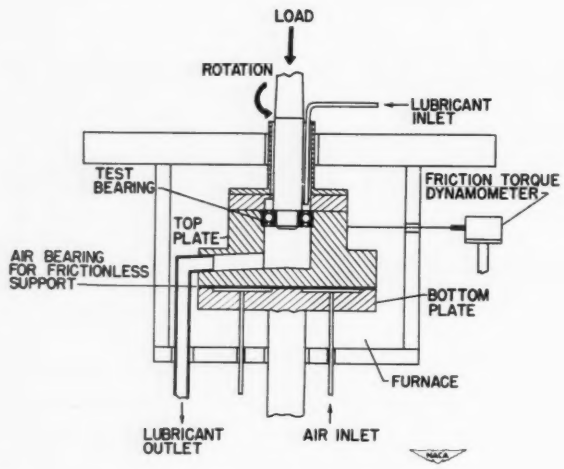


Figure 1. Schematic diagram of bearing test rig.

The two gases were mixed in a 4-oz. bottle and then introduced to the test bearing cavity through the lubricant inlet tube (see Figure 1). In order to prevent seepage of other gases into the test-bearing cavity, a slight positive pressure was maintained in the test-bearing cavity.

In no test was a bearing run continuously for more than 8 hrs. (the length of a work shift). Therefore all tests, other than those in which bearings failed in a short time, were shut down and restarted at least once.

PROCEDURE

All runs were conducted at a constant speed of 2500 rpm, 110 lb. thrust load, and constant temperature. Tests were run at bearing temperatures of 550, 700, and 850° F., but the greater portion of the work was done at 850° F. A test was ended when either failure occurred or when 20 hrs. running time had been accumulated. A failed bearing is a damaged bearing that becomes inoperative. Failure occurs in stages, and in many of the tests bearings were not run to complete failure. One of the signs of early stages of failure is high (in excess of 0.5 in-lb) and unstable friction torque. The other is noisy operation. Cage breakage usually occurred when the test was not stopped soon enough. While a torque value of 0.5 in-lb for failure indication is arbitrary, it is based on experience in this test rig. Generally, failure occurred when 0.5 in-lb torque was exceeded.

Two series of tests were run. In one series, the oil-flow rate was held constant at 15 drops per min., and the air content of the gas mixture supplied to the test bearing varied to obtain the desired oil-oxygen ratios. In the second series, the atmosphere composition was held constant at 20 per cent air, while the oil flow was varied to obtain the desired oil-oxygen ratios.

Some of the tests were rerun to check the reproducibility of the results. It was found that the time to failure could be duplicated within about 10 per cent.

RESULTS & DISCUSSION

The absolute values obtained in these tests are, of course, completely dependent on the characteristics of the test rig and on the operating conditions.

The bearing temperatures at which these tests were run exceed those of present engines and even those predicted for future engines.[1] The severity of operating conditions in these tests are, however, much lower than those of actual engine applications. The trends illustrated by the test data are the really important results, and these are believed to be less dependent on the rig.

Effect of Temperature

The results of 3 series of tests run at 550, 700 and 850° F. at an oil flow of 15 drops per min. (0.0002 lbs/min), and various percentages of air in the atmosphere are shown in Figure 2. At 550° F., effective lubrication (as indicated by a 20-hr. run without failure) was obtained over the entire range of 0 to 100 per cent air in the atmosphere. At 700° F., effective lubrication was obtained at 0 to 50 per cent air in the atmosphere, but not at 100 per cent air. At 850° F., effective lubrication was obtained only in a pure nitrogen atmosphere (0 per cent of air). Although all tests at 850° F. over the range 5 to 20 per cent air in atmosphere failed, the time to failure decreased with increasing per cent of air. At air percentages above 20, failures occurred almost immediately.

These curves indicate that, with increasing temperature, less oxygen is required to impair the lubricating effectiveness of a specific quantity of oil. As temperature is increased, the evaporation, thermal stability, and oxidation characteristics of the lubricant become more important. Because of the increasing rates of evaporation and thermal decomposition with increasing temperature, less oil is available at the higher temperature to lubricate the bearing. Thus, the higher the temperature, the higher the oil-oxygen ratios that are required to obtain effective lubrication.

Effect of Oil-Oxygen Ratio

The stoichiometric ratio for 1010 oil and air was found to be 0.0698 by chemical analysis. Expressed as an oil-oxygen ratio this becomes 0.301. At an oil flow of 15 drops per min., and a total gas flow of 0.12 cfm, the

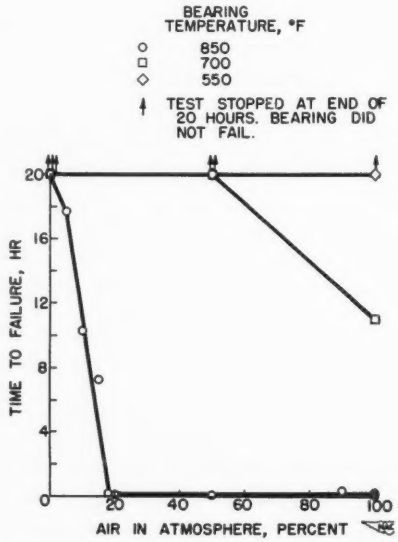


Figure 2. Effect of the percent of air in the ambient atmosphere on time to failure for 20 mm bore ball bearings with 1010 oil lubrication. Oil flow, 15 drops per minute (0.0002 lb/min); speed, 2500 rpm; load, 110 lbs. thrust; gas flow, 0.12 cubic feet per minute.

stoichiometric ratio occurs at 42 per cent air in atmosphere. At lower air percentages, therefore, the mixture is rich and at higher air percentages it is lean.

Figure 3(a) shows a plot of oil-oxygen ratio against time to failure for the data of Figure 2 at 850° F. The stoichiometric ratio is shown as a dashed vertical line. The plot shows that the average oil-oxygen ratio must be considerably on the rich side before effective lubrication begins. Since the data of Figure 3(a) were obtained at constant oil flow, the question arose as to whether the same criterion for effective lubrication holds for a variable oil flow. To demonstrate this point, a series of tests was made at 850° F., 20 per cent air in atmosphere, and oil flows from 15 to 52 drops per min. The results for this series of tests are shown in Figure 3(b). It is evident that similar relationships between the oil-oxygen ratio and effective lubrication hold both for constant and variable oil flow.

As shown in Figure 3(b), bearing failure can be delayed by supplying rich mixtures. At a constant oxygen concentration in the atmosphere, the time to failure can be increased (to 1.3 hr. from a value close to 0) by supplying 28 drops rather than 15 drops per min. Bearing life was over 20 hr. with 34 or more drops per min. of oil (oil-oxygen ratio, 1.53). At a bearing temperature of 850° F., and oil-oxygen ratios of 0.61 and higher, there is apparently enough oil on the bearing so that evaporation and thermal decomposition do not remove it completely. The increase in time to failure with increased oil flow is due to the fact

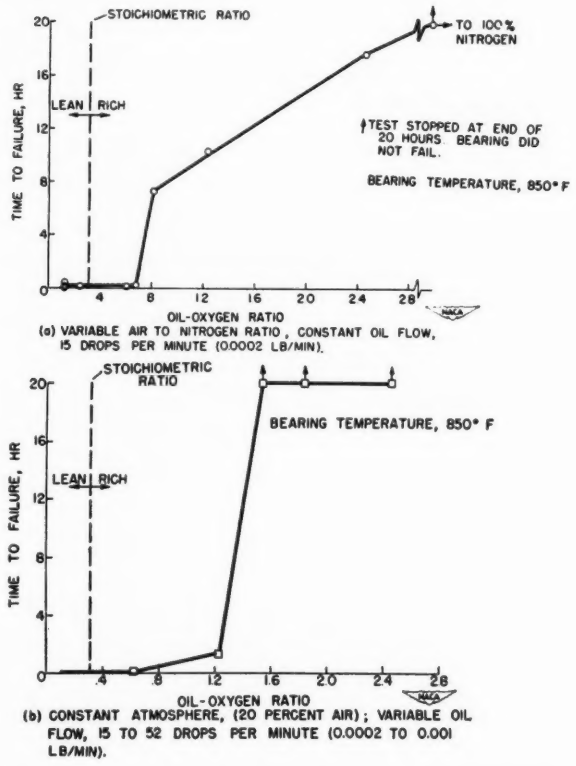

STOICHIOMETRIC RATIO
TO 100% NITROGEN
LEAN
RICH
TEST STOPPED AT END OF 20 HOURS. BEARING DID NOT FAIL.
BEARING TEMPERATURE, 850° F
TIME TO FAILURE, HR
OIL-OXYGEN RATIO
(a) VARIABLE AIR TO NITROGEN RATIO, CONSTANT OIL FLOW, 15 DROPS PER MINUTE (0.0002 LB/MIN).
STOICHIOMETRIC RATIO
BEARING TEMPERATURE, 850° F
LEAN
RICH
TIME TO FAILURE, HR
OIL-OXYGEN RATIO
(b) CONSTANT ATMOSPHERE, (20 PERCENT AIR); VARIABLE OIL FLOW, 15 TO 52 DROPS PER MINUTE (0.0002 TO 0.001 LB/MIN).

Figure 3. Effect of oil-oxygen ratio on time to failure for 20 mm bore ball bearings with 1010 oil lubrication. Speed, 2500 rpm; load, 110 lbs. thrust; gas flow, 0.12 cubic feet per minute.

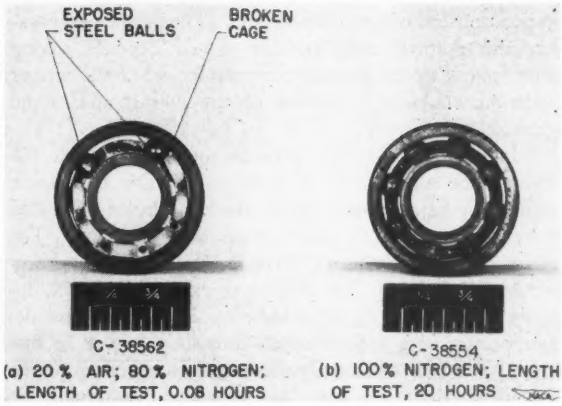

EXPOSED STEEL BALLS
BROKEN CAGE
C-38562
(a) 20% AIR; 80% NITROGEN; LENGTH OF TEST, 0.08 HOURS
C-38554
(b) 100% NITROGEN; LENGTH OF TEST, 20 HOURS

Figure 4. High-temperature bearings after tests with 1010 oil at bearing temperature of 850° F.

that the available oxygen cannot oxidize all of the lubricant which is not evaporated or thermally decomposed. Because oil flows were very low, surface cooling of the bearing due to vaporization of the oil is believed to be negligible.

Test Bearings after Test

In general, the test bearings were fairly clean after test. Carbonaceous deposits were somewhat heavier at 550 and 700° F. than at 850° F., probably because of heavier oil films on the bearings at the lower temperatures (due to lower evaporation rates). Excessively heavy deposits could cause eventual failure. Two of the bearings lubricated with 15 drops per min. are shown in Figure 4 to illustrate the effect of oxygen in the atmosphere. The bearing of Figure 4(a) failed after only 5 min. of running in 20 per cent air and 80 per cent nitrogen. The bearing of Figure 4(b) was run in 100 per cent nitrogen and was undamaged, although slightly discolored, after 20 hours.

DISCUSSION OF RESULTS

The results indicate that, under the conditions of these experiments, lubrication of rolling-contact bearings at elevated temperatures is possible with a liquid-petroleum lubricant. In order to obtain effective lubrication, an oil film must be maintained between the bearing surfaces in rolling and sliding contact. It has been found[13] that only minute quantities of oil are required to lubricate a bearing of this size, running at this rpm at normal temperatures. At high temperatures, however, some oil is lost by evaporation, some by oxidation, and some by thermal decomposition. Therefore it might be hypothesized that the total oil flow required to obtain effective lubrication at high temperature is qualitatively composed of four parts in the following time sequence: (a) the quantity lost by evaporation before entering the bearing, (b) the quantity which the available oxygen can oxidize, (c) the quantity which thermally decomposes, and (d) the quantity required to provide a lubricant film in the bearing.

The graphs in Figures 2 and 3 seem to illustrate these points. For a given time to failure, Figure 2 shows that, with increasing temperature and constant oil flow, the amount of oxygen that can be tolerated decreases. These results show that in order to maintain the amount of lubricant required for lubrication, less oil can be allowed to oxidize, since the higher temperatures result in greater

evaporation and decomposition rates. The rates of evaporation and thermal decomposition would depend, among other factors, upon time and temperature, while the rate of oxidation would be a function of temperature and of the available oxygen.

In Figure 3, the "lag" between the stoichiometric oil-oxygen ratio and the ratios at which effective lubrication begins may be accounted for by the quantity of oil which is lost by evaporation and thermal decomposition. The longer lag at the higher oil flows in Figure 3(b) [as compared to Figure 3(a)] is difficult to explain, since the opposite effect would be expected with evaporation and decomposition rates approximately constant. It may be that larger quantities of decomposition products collect in the bearing at higher oil flows, and that these decomposition products are detrimental to effective lubrication.

Since the oil was introduced in drop form, the oil-oxygen ratios are supply values only and may not be representative of the conditions at the bearing. A portion of the oil is not available to mix with the gas because it evaporates very rapidly and escapes from the bearing cavity. The oil-oxygen ratio probably varies during the time interval between drops. This can be understood better by considering what happens to the oil drop in one cycle. First, the oil evaporates as it drops through the hot gas. Second, most of the unevaporated portion of the oil drop is broken up into many small droplets when it strikes the bearing, the remaining portion clinging to the bearing as a film of liquid. The time required for complete evaporation of a small oil droplet is very short, because it is directly proportional to the square of the initial diameter of the droplet.[14] The fractions of the droplet which are not evaporated or oxidized either may be blown from the bearing cavity or may again strike the bearing and contribute to the lubricant film. The oil film left on the surface provides lubrication only as long as it remains on the bearing before the next oil drop comes. However, this film on the bearing is also subject to evaporation, chemical breakdown, and oxidation. The life of this film at constant oil flow is a function of the temperature and the amount of oxygen present.

Work with larger bearing sizes at higher speeds and oil flows is necessary before results obtained here can be generalized. Factors such as the amount of lubricant evaporation and the degree of deposits on the bearing that can be tolerated will become important.

SUMMARY

Tests of 20-mm-bore ball bearings lubricated with grade 1010 oil introduced in drop form were conducted at bearing temperatures of 550, 700, and 850° F., and at 2500 rpm. Test results indicate that temperature and the ratio of oil flow to the amount of oxygen available in the atmosphere are important variables. It is hypothesized that effective lubrication can be maintained if the oil-flow rate exceeds that lost by oxidation, evaporation, and thermal decomposition. Therefore, oil-oxygen ratios must be greater than the stoichiometric ratio.

At a bearing temperature of 850° F., and an oil-flow rate of 0.0002 lb per min., effective lubrication was obtained at zero air flow rate (100 per cent nitrogen atmosphere). However, at this temperature and oil flow, failure occurred almost immediately in an atmosphere of 20 per cent air and 80 per cent nitrogen. An increase in oil flow from 0.0002 to about 0.0004 lb. per min. in this atmosphere increased the time to failure from 0.08 to 1.3 hr.

BIBLIOGRAPHY

1. "Review of Current and Anticipated Lubricant Problems in Turbojet Engines," by NACA Subcommittee on Lubrication & Wear, NACA RM 51D20, 1951.
2. Cross, R. I., "Synthetics Help Meet Stiff Lube Need of Turbo Engines," *SAE Journal, 62*, March 1954. (Based on Questions and Answer Forum on "Synthetic Oils for Aircraft Gas Turbines" held during SAE Annual Meeting, Detroit, Mich., January 14, 1953.)
3. Hunt, K. C., "Petroleum Requirements of British Gas Turbines. Part II — Lubricants," *SAE Journal, 59*, November 1951, pp. 20-21.
4. "Synthetic Oils for Aircraft Gas Turbine Lubrication," (anonymous), *Lubrication, 40*, April 1954 (published by The Texas Co.).
5. Townsend, G. P., "Trends in Design of Aviation Gas Turbine Lubrication Systems." Paper presented at Semi-Annual Meeting, Pittsburgh, Pa., June 20-24, 1954, of the American Society of Mechanical Engineers.
6. Nemeth, Z. N., & Anderson, W. J., "Temperature Limitations of Petroleum, Synthetic, and Other Lubricants in Rolling Contact Bearings." Paper No. 412, presented at the SAE National Fuels & Lubricants Meeting, Tulsa, Okla., November 4-5, 1954.
7. Macks, E. F., Nemeth, Z. N., & Anderson, W. J., "Preliminary Investigation of Molybdenum Disulfide — Air-Mist Lubrication for Roller Bearings Operating to DN Values of 1×10^6 and Ball Bearings Operating to Temperatures of 1000° F.," NACA RM E51G31, October 1951.
8. Nemeth, Z. N., & Anderson, W. J., "Exploratory Investigation of Temperature Limitation of Various Lubricants for High-Temperature 20 Millimeter Bore Ball Bearings," NACA TN 3337, 1955.
9. Nemeth, Z. N., & Anderson, W. J., "Effect of Air and Nitrogen Atmospheres on the Temperature Limitations of Liquid and Solid Lubricants in Ball Bearings," *Lubrication Engineering, 11*, July-August 1955.
10. Johnson, R. L., & Bisson, E. E., "Bearings and Lubricants for Aircraft Turbine Engines." Paper presented before SAE Annual Meeting, Detroit, Mich., January 10-14, 1955.
11. Godfrey, D., & Nelson, E. C., "Oxidation Characteristics of Molybdenum Disulfide and Effect of Such Oxidation on Its Role as a Solid-Film Lubricants," NACA TN 1882, 1949.
12. Sorem, S. S., & Cattaneo, A. G., "High-Temperature Bearing Operation in the Absence of Liquid Lubricants," Shell Development Co., Emeryville, Calif., TR No. 230-53, Subject No. 5158.
13. Booser, E. R., & Wilcock, D. F., "Minimum Oil Requirements of Ball Bearings," *Lubrication Engineering, 9*, June 1953, pp. 140-143.
14. Kobayasi, K., "The Evaporation Velocity of Single Droplets of Liquids," *The Engineer's Digest, 15*, November 1954, p. 463, reprinted from Technology Reports of the Tohoku University, Vol. 18, No. 2, 1954, pp. 209-222.

12th ASLE Annual Meeting & Exhibit

April 15-16-17, 1957 **Sheraton-Cadillac Hotel, Detroit**

Organization of a Plant

Lubrication Program-II

O. J. Seidl
Plant Engineer
Combustion Engineering, Inc.*

Editor's Note: **This paper represents the second of a series of three articles on organizing the plant lubrication program. This first paper was published in the July-August issue of the journal and the final will be published in a future issue.**

INTRODUCTION

In organizing the plant lubrication program at the East Chicago Division of Combustion Engineering, Inc., a sequence of events had to be considered and carried through. The objective of this paper will be to review these events in comparative detail and in the approximate sequence that they occurred. Needless to say, some of the steps were planned and organized simultaneously.

The East Chicigo Division is considered to be a medium-sized manufacturing plant employing approximately 1100 workers. In area, the Division covers approximately 32 acres, of which 10 are under roof and used for manufacturing purposes. Our products are predominantly superheater and reheater units for power boilers and coal pulverizers. Thus, the best description one can apply for the shop is that of a metal fabricating job shop. Approximately 1000 electric motors ranging in size from the fractional to 50 horsepower are used. Insofar as machine tools are concerned, there are all sizes of horizontal and vertical boring mills, drill presses, tube bending machines, turret lathes, engine lathes, and other various and sundry items for fabricating metal. There are 18 overhead cranes which span anywhere from 55 to 90 feet and which range from 5- to 20-ton capacity. For material handling and transportation, 41 pieces of automotive equipment are utilized, including such items as fork trucks, straddle carriers, side loaders, trucks, and station wagons. In addition to this there is a full complement of air compressors, boilers, air conditioning equipment, unit heaters, and other items of this nature, which are necessary to keep this plant operating.

Now that we have pictured in our minds the size of the facility, we will talk about the lubrication practices which were followed prior to the organization of the new program.

LUBRICATION RESPONSIBILITIES

The responsibility for the proper lubrication of machine tools was in the hands of the foremen of each department. He determined the type of oil which was to be used, the frequency with which the lubricating process was to be carried out, and the procurement of necessary equipment. The oils and greases required were requisitioned from the storeroom either in drum lots or smaller quantities. We should now look at Figure 1, which shows a corner of the old oil storage building. The disbursement of oils in less than drum lots was made from this area. First, you will note that the oils which were received from the vendor had to be transferred from their original container to the containers shown, immediately introducing a possibility of contamination. There was also the possibility of having the wrong grade of oil pumped into the wrong reservoir. Obviously, the machine-tool part which required a particular type of oil might not get the oil required. Also notice that the coding of the oil was not at all in line with good practice. Such pet names as "electric motor oil", "black oil", and "machine oil" were quite common.

A very good example, shown here, is the reservoir purportedly containing "black oil". (Since the original survey a code number was hurriedly applied.) As you know, black oil is the name used for summer black oil, winter black oil, cutting oil, and several others. One can imagine the dilemma imposed on the inventory control office when a requisition for black oil came in. Far more serious, of course, was the fact that in all probability the machines were not getting the proper oils.

When the use was extensive enough, the shops requisitioned the oils by the drum. In such cases they were scattered about the bays, usually with the bung cap removed. As a result, one could be reasonably sure that the oil which was going into the machine had been contami-

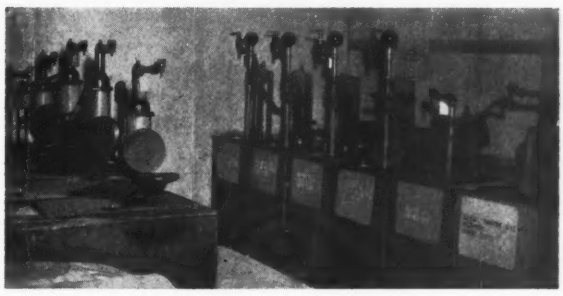


Figure 1. Lubricant storage area before installing the lubrication program.

*425 W. 151st Street, East Chicago, Indiana

(This paper was sponsored by the Technical Committee on Principles and Practices of Economic Lubrication, presented at the 10th Annual Meeting of ASLE, Chicago, April 14, 1955.)

nated with grit or other abrasive particles.

We were aware, too, that some foremen gave the lubrication of their equipment more attention than others. Of course, since all people place different values on different things, this was only to be expected.

Our supervisors and machine operators are no different than those who work in other places. Without the proper tools and plans, only the most exceptional people have even the slightest chance for doing a good job, be it lubrication or anything else they are called upon to do. The proof of this lies in the full measure of cooperation which we received from all concerned.

Reorganization

One can see now that there were many reasons why it was necessary to reorganize the entire lubrication program. Of the several reasons, there were none in particular which one could call most important, since we felt that all were equally important with but one exception, and that they all added up to a savings in dollars in one way or another. First, it was our intention to initiate a scheduled or planned maintenance program. It was realized that without a well-organized lubrication program, any kind of planned, scheduled or preventive maintenance program would have little chance for success.

PROGRAM GOALS

With the proposed program we expected to increase the life of our machine tools. There wasn't much doubt in our minds about this since we had experienced many, many cases of bearing falure due to lack of proper lubrication. Excessive wearing of machine ways could also be attributed to inadequate procedures and contaminated lubricants.

Another aim was to decrease the $20,000 spent annually for the various lubricants. We felt that this sum could be reduced not only by using fewer types of oils, thus reducing inventory, but also by decreasing waste. By reducing the number of oils, storage space would be reduced and there would be a more rapid turnover, thus keeping the oils fresh, and requiring a less complicated inventory control system.

The reason for the large variety of oils and greases was rather obvious. One of the glib talking salesmen from some oil company would convince a foreman that his particular oil, and that oil alone, would do the job for him. As a result, the foreman ordered the oil, perhaps in a sizeable quantity, which in all probability would last him a good number of years, since no one else used it. In making the survey, items were found which, based on current usage, would take several years to consume.

We also felt that with a planned and integrated program handsome savings in direct labor dollars would be realized. In all cases highly paid machinists were given excessive allowances for greasing, oiling, and cleaning, and it appeared to us that a trained lubricator could do a better job in less time.

For these reasons then, we were convinced that there existed a very definite need for the program. Since we had the complete backing of our management—and I must strongly emphasize at this point that without full backing the program can not be put into effect—our task was to formulate the program.

PROGRAM GUIDANCE

Our Division was not large enough to utilize the services of a full time lubricating engineer, hence, it became necessary as the first step to find another source for competent lubrication engineering services.

After some very careful thought we chose to ask the Engineering Department of one of the major oil companies to assist us in putting our program across. Several preliminary sessions were held in which we exchanged views on what we thought we would like to have and the type of service they would be able to render. It was at these sessions where we outlined our program and the sequence in which the various steps could be activated.

Machine Identification

It was generally agreed that the first thing we would have to do would be to renumber all of our machinery and equipment. The practice of numbering machines and equipment had been followed in the past, but due to wear and tear, many of the metal tags had become badly mangled or were missing entirely. Also it was thought best to renumber because our method of recording machinery and equipment information at the maintenance office was not at all adequate. Briefly, it consisted of recording the name of the machine and its number on one line in a book. Since we were going to get into a comprehensive preventive maintenance program, it would be necessary to have complete and accurate data on a separate card for each machine. We chose to keep this record in what is commonly known as a visible record system. There are several manufacturers of this type of equipment. On each record pocket there were slots for holding two cards side by side. One card we call our Equipment Record Card and the other our Electrical Equipment Record Card. Each machine was given a number and the motor for that machine had the same number with a letter suffix. If there were more than one motor, the largest was given the suffix letter A, the next largest, B, and so on down the line. Thus, as an example, a horizontal boring mill with four motors would be assigned to number 1900, with 1900A, 1900B, 1900C, and 1900D tags to take care of the four motors. The actual tag used for identifying the machine was made of brass with the company and division name stamped on as well as the machine number. With the visible record system, the time for major lubrication attention can be seen easily by means of a red marker, or what we call a flag.

Lubrication Survey

All of this basic work was accomplished by our personnel. After it was finished we were in a position to run an accurate lubricating survey of all of the equipment. The lubricating survey was conducted by the lubrication engineer from the firm that we had chosen, with the help of one of the project engineers of the Plant Engineering Department. This survey was made for the purpose of recording all essential data necessary to properly lubricate each individual machine. The surveying engineers, of course, kept in mind the desirability of minimizing the number of oils and greases. Table I indicates a sample of the data that were recorded. In the left hand column the machine numbers are shown. Immediately to the right of the number is the description of the machine, followed by the department in which it is located. Listed directly below each machine description is the necessary lubricating information. Let us take machine number 1144 as an example. This is a milling machine located in Department 406. It shows that the lubricator oil cups are to be taken care of daily with X-brand oil No. 2. The letter D stands

Table I
Lubrication Survey Data

Equipment		Frequency	Lubricants Recommended*
1136 Hydraulic Pump—Dept. 02	Grease Cups	D	X-Brand Grease No. 1
1137- 1138- 1139- 1140 Blowers—Dept. 101	Motor Bearings — Sealed	—	No lubrication required
	Motor Bearings — Greased	Y	X-Brand Grease No. 1
1142 Spot Welder—Dept. 101	Air Line Oiler	D	X-Brand Oil No. 1
	Grease Fitting	W	X-Brand Grease No. 1
1143 Drill Sharpener—Dept. 101	Piston Slide	D	X-Brand Oil No. 2
	Air Cylinders	D	X-Brand Oil No. 1
1144 Milling Machine—Dept. 406	Lubricator Oil Cups	D	X-Brand Oil
	Table Drive Worm	W	X-Brand Grease
	Elevating Screws	M	X-Brand Compound
	Drive Transmission	M-Y	X-Brand Compound
	Auxiliary Cutter, Motor Gear Case	M-Y	X-Brand Compound
	Auxiliary Cutter, Worm Drive	M-Y	X-Brand Oil No. 3
	Grease Fittings	W	X-Brand Grease No. 1
1145 Swage No. 306—Dept. 101	Circulation System	W-Y	X-Brand Oil No. 2
	Enclosed Gears	W-Y	X-Brand Oil No. 3
	Slides and Ways	D	X-Brand Oil No. 1
	Grease Fittings	W	X-Brand Grease No. 1
1147 Type E Support Welder—Dept. 502	Air Line Oiler	D	X-Brand Oil No. 1
1148 Cut Off—Dept. 101	Oil Cups	D	X-Brand Oil No. 1
	Spindles (Packed)	Y	X-Brand Grease No. 1

Note: M-Y means monthly check and yearly change

**Trade names have been replaced by the designation X-Brand*

for daily, W for weekly, M for monthly, and Y for yearly. Listed elsewhere in the survey were the code letters for the various oils and greases. The purpose of the code letters is to serve as a means of identification at the point of application. Thus, where X-brand oil No. 2 was to be applied, the code letters for this designation appeared stenciled.

We had now reached the point where we knew all of the details concerning lubrication about each machine, and the next step was to set up the organization insofar as personnel were concerned.

PERSONNEL TRAINING

Since this was going to result in a somewhat radical departure from the then existing practices and the possibility of encountering unnecessary resistance was apt to occur if all people concerned were not properly trained or educated, it was decided that a very thorough orientation program was in order. The training, which consisted of a series of lectures by the lubricating engineer from the oil company, was given to all of our production and maintenance supervisors. The lectures covered all of the aspects of the program together with lubrication fundamentals, that is, properties of oils, function of additives, and nomenclature. It wasn't until we had finished indoctrinating the supervisors that we started training our lubricators.

SELECTING THE LUBRICATORS

Before we could start this training, however, it was necessary to clarify in our minds the job content for the lubricator. We wanted our lubricators to concern themselves with lubricating all of the equipment in the plant with the following exceptions. We would continue to have our overhead crane repairers lubricate all overhead cranes, the power plant operators would continue to lubricate the equipment in the power plant, the automotive equipment would still be handled by the oiler in that section, and an electrician would still be assigned to take care of the electric motors. Based on this breakdown, we estimated that two machine tool lubricators could handle the entire plant. We also felt strongly that if the lubricator was going to do the job we wanted done he would have to be paid accordingly. We were not going into this program under the assumption that any sweeper could do the job properly. With the job evaluation system that we have in operation, it was necessary to write a job description. It was our intention to put in only the factors and duties which we fully expected accomplished, without attempting to load it, so that we would arrive at a certain point value which is then translated into dollars and cents of hourly pay. The point value resulted in a classification which was one grade lower than our grade for millwrights. With this result, we were in a position to attract people who would do justice to the assignment. The subject job description follows.

JOB DESCRIPTION

Job Title — *Machine and Equipment Lubricator*
Department Name — *Millwright*

Responsible for identifying different oils by their code numbers and proper lubrication of all types of machinery and equipment in the plant. Must be able to use lubrication equipment and components and differentiate between the various lubrication fittings and supply the proper amount of the right kind of lubrication. Adjust and make minor repairs to automatic lubricators. Must be able to read machinery blue prints, interpret lubrication instructions as set forth in lubrication manuals, and be able to keep simple legible records. Should be in good enough physical condition to permit climbing, working in awkward positions, handling of lubrication cans and equipment, with eyesight that will enable him to avoid moving machinery and dangerous electrical equipment. Containers of lubricants and all lubricating equipment must be kept clean. Make repairs of lubricating equipment, such as grease, guns, etc. Conduct reclamation of lubricants by use of a filter. Lubrication of instruments such as recorders, etc., will require special precaution and mechanical knowledge. Must be able to use the various kinds of machine tools and the functions of the various parts and be able to recognize potential failure as well as failures of lubricating. Must qualify as a good mechanic in general knowledge of machinery. Have enough knowledge of electrical equipment to recognize danger to self during administration of his duties. Must have clerical ability to maintain records and refer to and fill in forms regarding sequence of lubrication and type of lubricant to use and follow directions of coding a machine, that is, by means of stencils or tags. This man will be required to code new machines and keep coding up to date on old ones. Should be alert to recognize potential failures of machinery and especially so with regards to failure caused by faulty lubrication. Install or replace oil wipers, fittings, etc. Works under supervision of foreman and/or assistant foreman.

We were fortunate from the standpoint of being able to select men not only with sufficient seniority, but also those who were exceptionally well qualified temperamentally and mechanically. The matter of having properly suited people cannot be too strongly emphasized since it is the absolute heart of the program. Regardless of the infinite care and planning used, unless these plans are executed in the manner expected, the entire project becomes null and void. After the lubricators were chosen, the task of training them was started.

Equipment and Facilities

About the time that we started on the personnel program, we also started planning for the lubricating area and the procurement of the equipment. Since we felt that the storage practices being used were not satisfactory, we developed a new method. Figure 2 shows that the drums as they are received from the vendor are placed for temporary storage on simple racks. Fork trucks equipped with load-grab attachments are used to load and unload drums. Having an outside storage area still does not give us ideal facilities and when conditions permit we will attempt to place the racks under a heated covered area. From this outside holding area the lubricants, in their original containers, are brought to the lubricating area. Figure 3 pictures one corner of the area that is used by our lubricators. Note that the lubricants are still in their original containers. Thus, to this point we have still not introduced any possible chance for contamination. The drums are all clearly marked with the brand names, and although not shown here, these brand names also appear on the wall directly over each container, along with the code letters. This tagging minimizes any possibility of substitution.

Figure 4 pictures a general view of the lubricating area. From this photograph one can see the space allocated to the lubricators and obtain an idea of the facilities in the area. Notice a work bench, the various lubricants, some central storage racks, and one of the lubricating carts. Each lubricator has his own lubrication cart.

Figure 5 shows a close-up of the cart that the lubricators wheel about the shops. These units were designed and built by our Division, since we were unable to locate a commercial model. One standard item is the truck on which the cabinet is placed. It can be purchased from any equipment supply house. The cabinet is made from angles, sheets, and standard drawers. The top drawer is used for holding various fittings. The center drawer contains 5 X 7 inch cards, each in a separate clear plastic folder. These cards, one for each machine, contain the same information as was shown on the lubrication survey and serve to guide the lubricator while he is making his rounds. The plastic folders keep the cards in a legible condition. Clean wiping rags are kept in the third drawer, and the bottom pan is for soiled rags. In this photograph, the type of containers, oil cans, and grease guns used can be seen. The safety

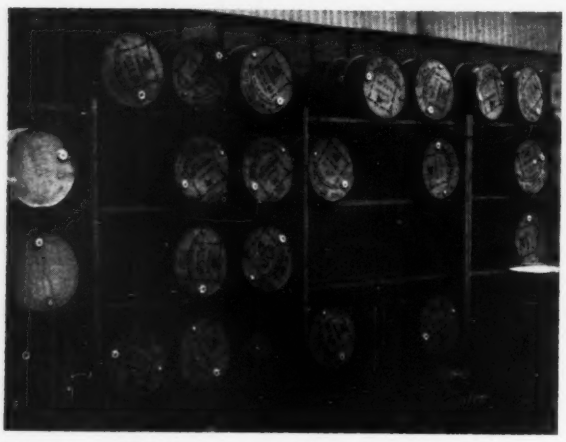


Figure 2. **Oil drums received from the vendor are placed on racks for temporary storage.**

Figure 3. **Direct dispersing area for oils under the new program.**

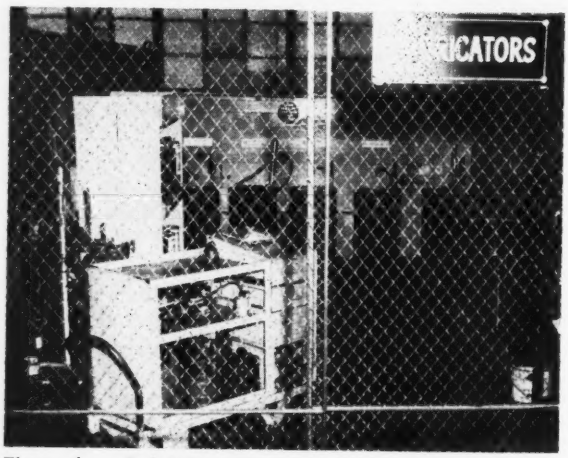


Figure 4. **Lubricating area showing one of the lubricating carts.**

Figure 5. **Cart used by the lubricator. Each man has his own cart.**

cans on the bottom shelf are filled directly from the original container. We feel this design minimizes the opportunity for contamination. The oil cans shown are of the positive feed type, equipped with flexible nozzles for reaching into the difficult spots that require lubrication.

Figure 6 illustrates how a grease gun is filled from the original container and also shows the small opportunity there is for contamination. The grease is applied directly from the gun to the machine.

The next step to be reviewed concerns the organization of the inevitable paper work system used for control. We believe that the best approach is to keep the system as simple as possible. Experience indicated that it would be much easier to add additional records as they became necessary in the future rather than to start with a bulky system initially and then attempt to eliminate some of these unnecessary forms later. With this approach in mind we initiated the following system. As was mentioned previously, data from the lubricating survey was transferred to 5 X 7 inch cards. These cards were made out in duplicate, one set going to the lubricator and one set for the Plant Maintenance Office. You will recall that these cards contained all of the information necessary for properly lubricating each machine.

In Figure 5, a clipboard can be seen on the right hand top shelf. This clipboard is to hold the forms shown in Table II. You will note that on these forms there is a space for the lubricator's name and the date. A new form is used daily enabling the lubricator to record all of his activities for the day. Whether he performs a daily, weekly, monthly, or any other operation, it is so recorded by a check mark. In the "remarks" column, he jots down any unusual conditions that he finds, such as faulty lubricating devices, worn wipers, or unusual wear and tear. The forms are reviewed daily by the supervisor for appropriate action. Each week the maintenance clerk prepares a list of the machines which require either their monthly, quarterly, semi-annual, or annual oil change or check. This information is picked off very rapidly from the visual flagging system used in conjunction with our equipment record cards. From the daily log, the maintenance clerk makes the necessary visual flagging adjustments so that it will show the time for the next inspection.

Our oils and greases are requisitioned from the storeroom in drum or sealed-container lots. The storeroom is responsible for maintaining a minimum-maximum control on this inventory. These maximum-minimum requirements were set up on a considered judgement basis and subject to review periodically by our maintenance supervisor.

RESULTS

The program has now been in full operation for about nine months, and the benefits derived are summarized as follows. One of our goals was to reduce the number of lubricants. In this we have been successful, as the number has been cut in half. One can visualize that this has greatly simplified the ordering, storage, and inventory problem. To assign a dollar savings value to this improvement, of course, would be extremely difficult and obviously inaccurate.

Figure 6. Greases are dispensed directly from the container to the gun in this area to diminish contamination possibilities.

The first few months of the operation pointed out to us very vividly that the practices of refilling and checking hydraulic reservoirs had been extremely bad, since many contained contaminated and/or inadequate quantities of fluid. For some time we were kept quite busy repairing leaks which had existed, but never had been brought to our attention. Certainly, there has been a savings involved here even though again the value is too elusive for accurate computation.

Direct dollar savings which we have been able to ascertain was computed on the basis of the reduction in oiling, greasing, and cleaning allowances given each machine operator. We, of course, were not able to eliminate this allowance completely, as we still hold the operator responsible for keeping his machine clean. At any rate, the savings resulting from this reduction in allowances more than pays the salaries of the lubricators. It was thought that this might be a troublesome spot, but as it turned out the operators are more satisfied since they are able to devote more time to production.

Table II
Lubrication Assignment Sheet

Lubricator_____ Date_____

Machine and No.	Location	Daily	Weekly	Monthly	Other	Remarks

Since the lubricator has been making his daily appearance we have found, too, that the machines are being kept in a neater condition. When operators show more interest in the care of their equipment we can all pretty well agree that the life of the machine tool will be extended. It seems that they care more because they are aware that we, too, care enough to have a man visit them each day with the proper lubricant, put in the right place, and at the right time.

Our lubricators are also an invaluable aid to our maintenance department in reporting points of potential failure and excessive wear. It was through the combined efforts of the lubricators and the maintenance department that we were able to develop and apply a wiper which has proven to be far more effective.

The problems that arise in setting up a program of this type are many, but we feel, from the short experience that we have had, that it has been very much worth our efforts. Any attempt to enter into a program such as this without the complete backing of the management would be impossible. Our success was possible because we had this backing, and the continued success will supply the incentive to keep the program going.

QUESTIONS AND ANSWERS

Q. What frequency of change of hydraulic oil have you established, and what quality level of hydraulic oil is being used?

A. I suppose the best that money can buy. We have three different hydraulic oils listed in the survey; one is a light oil, one a medium-heavy oil, and one a heavy oil. The light is a 150-second oil, the meduim 300, and the heavy, 900. The approximate SAE numbers are 10, 20, and 40-50 respectively. As to frequency of check or change, let me cite as an example a hydraulic press. The hydraulic system is checked weekly, and every six months we send a sample to the oil company and have them analyse it. If it is still good we leave it in. The same applies to other pieces of equipment which we might check yearly. These are the recommendations as they were submitted to us, and incidently, in a 16-inch boring mill we recently changed some of the hydraulic oil that had been in the system for five years. I have heard of turbines, which is a different field, where the oil has remained for 15 to 18 years.

Q. What is the approximate yearly cost?

A. Prior to this program we were using about $5000 worth of oil a year. Since we started the program the cost has gone up. We found that a lot of the reservoirs contained contaminated oils, and so forth, but as we get it lined up properly I am sure that the cost will go down. Right now I don't know what the new cost will be.

Q. Do you schedule your oil changes through the maintenance schedule department, and who opens and closes the large reservoirs?

A. Our lubricators are in the maintenance department and they are scheduled through the maintenance department. They open the reservoir, drain it, flush, clean it, put in new oil, and handle the entire operation.

Q. What is your line of promotion for the oiler?

A. We have not yet had this experience, but when the time comes, the lubricator will be promoted to the millwright classification.

Q. It was mentioned that in changing lubricant brands the oil suppliers are asked for their equivalent to the one specifically mentioned by the machine manufacturer. Is this not subject to error, or at least is it not less desirable than having the other oil supplier make his own machine survey and offer lubricant recommendations based on product application?

A. Maybe this is evading the question or not answering it precisely, but we have a large milling machine which has lead screws. We, too, wanted to standardize. We went to the machine manufacturer and asked if it were possible to substitute because we felt it desirable. We were told in no uncertain terms, and incidently this machine costs about 175,000 dollars, that the recommended product alone would do the job. So we did not change.

Q. Have you checked the leakage rate of hydraulic machines, and what is an acceptable leakage rate?

A. When you get a film of hydraulic oil on a particular machine it might be too much for that machine, yet where you have some pits excess oil might not bother you. Over a period of time you might accumulate a quarter of an inch of oil and not consider this amount excessive. I don't know which practice is best. You try to keep leakage down to a minimum.

Comment: In my opinion, the leakage on machines is just as low as good housekeeping can keep it, and that varies. What is considered acceptable in some places may be considered poor in other plants. How much time is available for protection, and how conscientious people are, what they consider waste: these are big variables. I have seen so much oil that you would think someone had opened a valve and drained it from some machines, yet people think nothing of it because the machine continues to work. I know of other plants where if a little oil is seen oozing out the maintenance people wonder what is wrong with the packing or the joint. What is acceptable? Acceptable leakage is what people are willing to accept and pay for without worrying about it. It is that variable. (*H. D. Krummel, Session Chairman.*)

In a food processing plant I imagine just a few drops of oil would be critical, but in a foundry with a sand floor leakage should not be a serious problem (Seidl.)

Q. Do you have any problem recruiting a corps of oiler men under the schedule and set-up that is practiced at Combustion Engineering? Do you get good stability and continuity of employment?

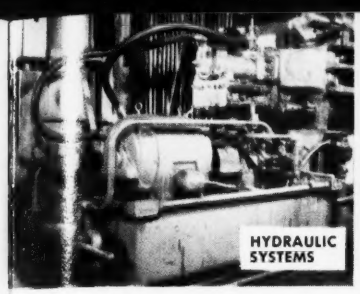
A. We have two oilers and the program has been in effect for only about 9 months. Both of these men have many years of seniority. We were fortunate to get them to take this job when one patricular process we had been running was completed. Because of having been on the production process they were never thoroughly indoctrinated into mechanics, so they were happy to take this assignment. As far as I can tell we will have them for a long time, because they have enough seniority, one fifteen years and the other eighteen, so that they won't be "bumped" off the job.

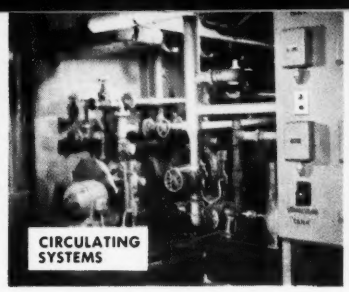
Q. Do you favor centralized lubrication application on machines not so equipped as originally purchased?

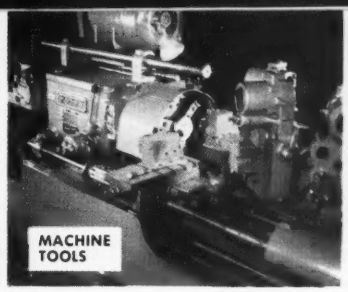
A. Yes. We are in the process of putting mechanical lubricators on a large boring mill.

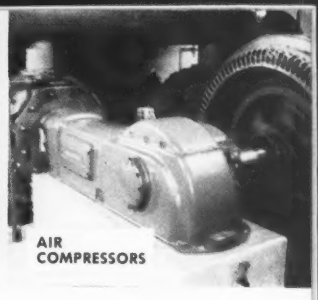
O. J. SEIDL

After receiving his BSME degree from the Illinois Institute of Technology in 1949, Mr. Seidl joined the staff of Combustion Engineering, Inc. He is responsible as Plant Engineer for all maintenance; tool, die, jig and fixture design; machine replacement analysis; and machine design. Mr. Seidl is a licensed professional engineer, member of NSPE, an associate member of ASME, and is active in the Calumet Chapter of Plant Engineers. He has contributed articles to *Plant Engineering* and *Supervision*. This is his first contribution to *Lubrication Engineering*.





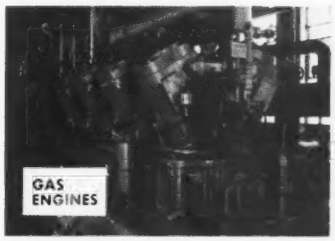


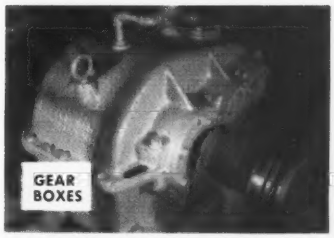


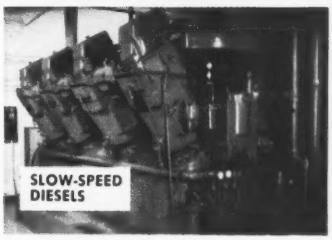
SUN SOLNUS OILS IDEAL LUBRICANTS FOR 80% OF ALL APPLICATIONS

Moderately priced...low in carbon-forming tendencies, Sun Solnus® oils simplify your storage problems by doing with *one oil* many jobs that would otherwise require *several.* Their ability to protect metal parts against corrosion, their resistance to oxidation, and their moderate price all add up to "more lubrication per dollar."

For technical information, see your Sun representative, or write to SUN OIL COMPANY, Philadelphia 3, Pa., Dept. I-51.







SUNOCO®

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY

PHILADELPHIA 3, PA.

© SUN OIL CO.

In Canada: SUN OIL COMPANY LIMITED, Toronto and Montreal

Valve on left is from compressor run for 3,000 hours with well-known, high-grade oil. At right is same valve after a 3,000-hour run with Sun Solnus oil. Note difference in carbon deposits.

3000-HOUR TEST PROVES SUN SOLNUS OILS REDUCE CARBON BUILD-UP IN COMPRESSORS

Equipment: A three-stage Norwalk horizontal-type compressor. Operating pressure: from 1,000 to 1,500 psi.

Test: The compressor was cleaned thoroughly and filled with a well-known, high-grade oil. The equipment was run for 3,000 hours, then torn down for inspection and cleaning. Then Solnus® 300 was tested in the same way.

Results: Look at the two pictures. You can see for yourself how Solnus oil reduced dangerous carbon build-up.

All types of reciprocating air compressors that have been changed over to a Sun Solnus oil show similar results. A test in your compressor will show the same remarkable reduction of carbon deposits.

You can get a technical bulletin about Sun Solnus oils by asking your Sun representative, or write to SUN OIL COMPANY, Philadelphia 3, Pa., Dept. I-52.

SUNOCO®

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY PHILADELPHIA 3, PA.

© SUN OIL CO.

IN CANADA: SUN OIL COMPANY LIMITED, TORONTO AND MONTREAL

(Personals, from p. 293)
a member of SAE, API, ASME, ASTM, Institute of Petroleum (London), Navy Advisory Committee on Fuels & Lubricants, and the 25-Year Club of the Petroleum Industry. His new address: Larcliff, 55 Taymil Rd., New Rochelle, N. Y.

(Current Literature, from p. 322)
troleum products according to ASTM method D-1160-52T. Apparatus is illustrated in its unitized laboratory-bench mounting pedestal, and specification details and prices are included not only for the complete apparatus, but for the individual glass parts as well. (Glass Engineering Laboratories, LE-12/5, 564 O'Neill Ave., Belmont, Calif.)

Information on Homogenizers. A new 6-page booklet on the use and selection of industrial homogenizers has been prepared that includes features of the Gaulin homogenizer, a capsule "Theory of Homogenization," information on the various types of products which can be handled, and a description of the five special Gaulin valve designs for handling fluid, viscous, slightly abrasive and very abrasive products. There is basic data for selection of the proper machine, covering over 100 distinct models, from 0 to 8000 psi and up to 6000 gph capacity. (Bulletin No. H-55, Manton-Gaulin Mfg. Co., Inc., LE-12/5, 44 Garden St., Everett 49, Mass.)

Corrosion Proofing Materials. A new brochure on corrosion proofing materials and techniques is offered that contains detailed information on cement mortars, interliners for masonry construction, and protective coatings and linings for surface treatment. Tables and charts are provided for selecting proper cement mortars and for determining resistance to various conditions; charts are provided for general use in selecting Pennsalt coatings or linings suitable in various corrosive ranges. (Pennsylvania Salt Mfg. Co., LE-12/5, 3 Penn Center Plaza, Philadelphia 2, Pa.)

Norgren NOW OFFERS

FASTER, BETTER LOCAL SERVICE

PHONE your nearby Norgren **District Representative and Distributor**

BALTIMORE, MD.
A. L. Hacker Co.
308 Wyndhurst Ave.
HOpkins 7-5700

BIRMINGHAM, ALA.
J. T. Sudduth & Co., Inc.
3017 Sixth Ave., South
AL 2-6101

BUFFALO, N. Y.
F. Bjerre Co.
120 Pierce Ave., Hamburg
EMerson 5282

CHARLOTTE, N. C.
L. W. Kinnear & Co.
1909 Shoreham Drive
EDison 2-6560

CHICAGO, ILL.
Walter Norris Engineering Co.
20 North Wacker Drive
STate 2-2804

CLEVELAND, OHIO
F. & W. Ursem Company
1548 West 117th Street
LAkewood 1-9136

DALLAS, TEXAS
Leo J. Schindler Co.
6007 Berkshire Lane
EMerson 7774

DAYTON, OHIO
K. C. Mosier Company
628 South Ludlow Street
Michigan 9805

DENVER, COLO.
E. C. Wild Company
695 South Garfield Street
SPruce 7-2852

DETROIT, MICH.
Wm. H. Nash Company
10300 Grand River Ave.
TExas 4-1111

FT. WAYNE, IND.
Neff Engineering Co.
2339 Crescent Avenue
EAstbrook 7391

HARTFORD, CONN.
Pearse-Pearson Company
1005 B. Farmington Ave. Plaza
JAckson 3-5261

KANSAS CITY, MO.
Ellis Akin Engineering Co.
2934 Cherry Street
WEstport 1-9189

LOS ANGELES, CALIF.
Teglen Engineering Co.
1942 Huntington Drive, So. Pasadena
PYramid 1-2856

LOUISVILLE, KY.
Charles Weber Company
536 Eastern Parkway
MElrose 7-2574

MILWAUKEE, WIS.
C. L. Thompson Company
4417 West Lisbon Avenue
HIlltop 4-4817

MINNEAPOLIS, MINN.
H. U. Rogness, Inc.
135 South 11th Street
FEderal 3-5595

NEWARK, N. J.
K. E. Knotts Company
106 Miln Street, Cranford
CRanford 6-3887

OKLAHOMA CITY, OKLA.
Nix Industrial Supply Co.
2702 South High
MElrose 7-5400

PHILADELPHIA, PA.
J. A. Moody Company
10 West Avenue, Wayne
WAyne 3441

PITTSBURGH, PA.
Leonard R. Nourie, Inc.
2414 West Liberty Avenue
LOcust 1-1628

PORTLAND, OREGON
Power Transmission Products
1107 Northwest 14th Avenue
CApitol 7-1271

SAN FRANCISCO, CALIF.
The Burke Company
1465 Bayshore Boulevard
DElaware 3-8261

SEATTLE, WASH.
George W. Warden Company
1305 Dexter Avenue
ALder 0622

SHREVEPORT, LA.
Harris Frederic & Company
100 Edwards Street
5-7455

ST. LOUIS, MO.
Sturgis Equipment Company
601 South Taylor Avenue
OLive 2-5380

SYRACUSE, N. Y.
Ralph W. Earl Company
530 East Washington Street
2-1655

CANADA

MONTREAL
Cowper Company Limited
515 Fourth Avenue
ME 7-6746

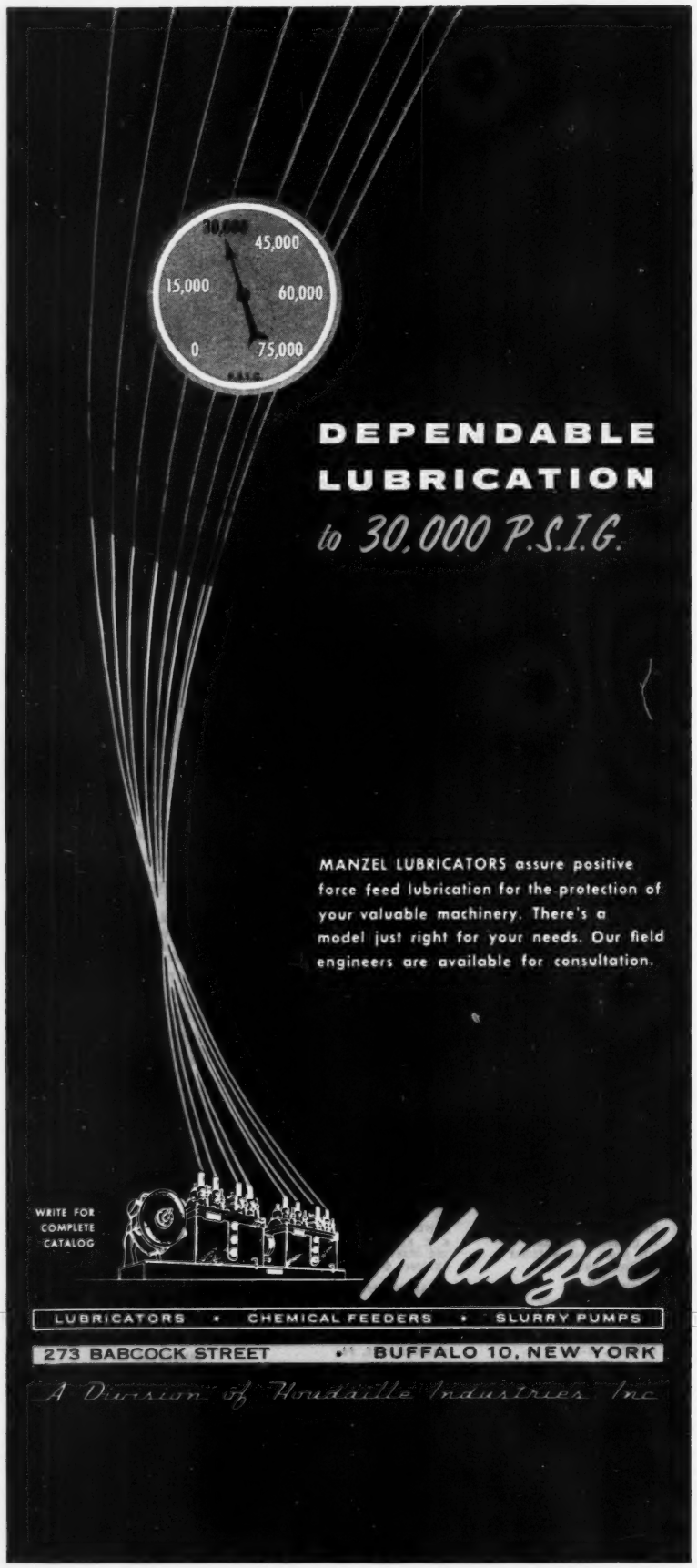
TORONTO
John Spotton Company Ltd.
21 Carson Street
CLifford 9-3788

VANCOUVER
Galbraith & Sulley Ltd.
1331 West 6th Avenue
CHerry 5121

C. A. Norgren Co.

C. A. NORGREN CO.
Wherever Air is Used in Industry

3434 So. Elati Street, Englewood, Colorado

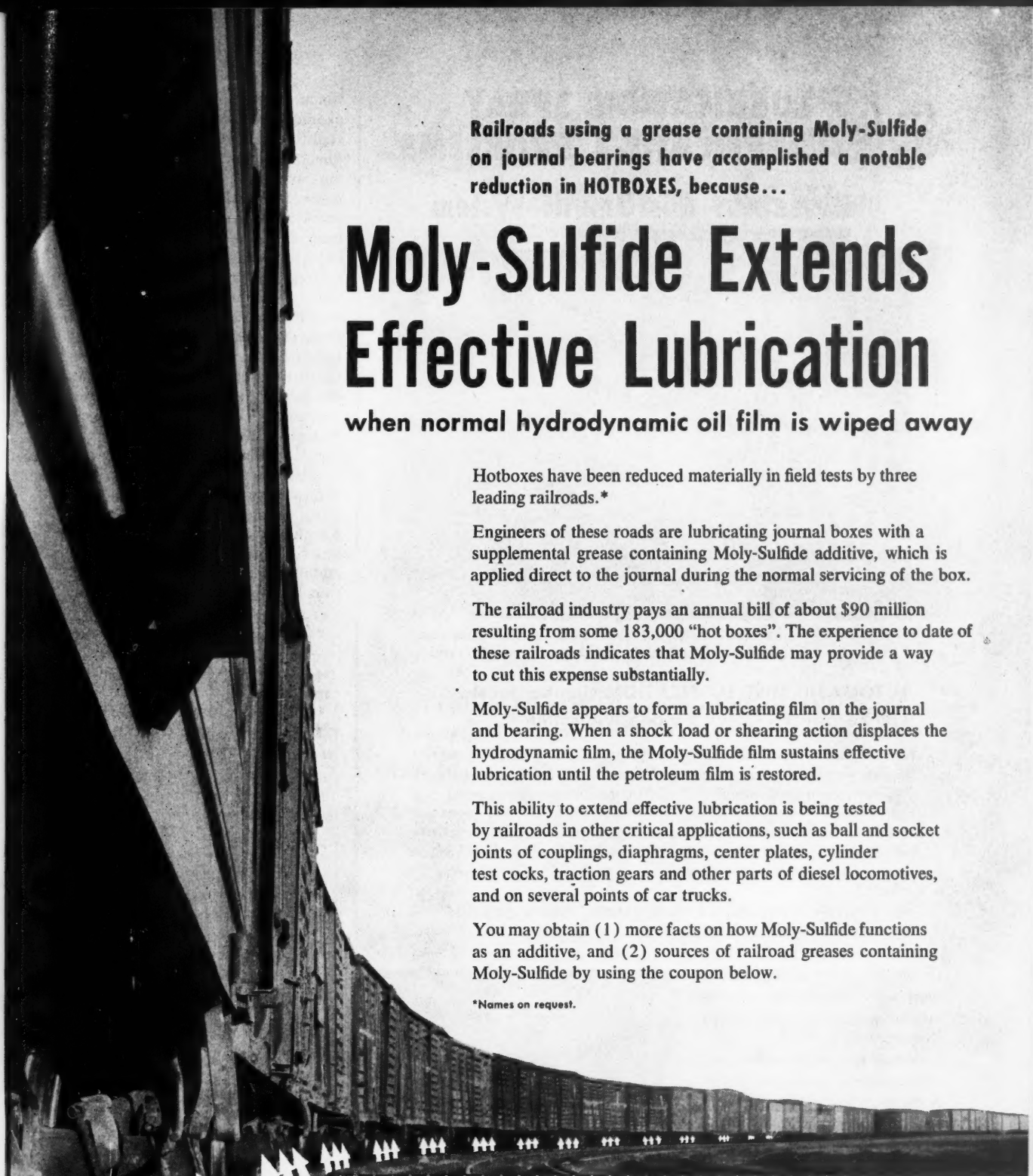

45,000
15,000
60,000
0
75,000
DEPENDABLE
LUBRICATION
to 30,000 P.S.I.G.
MANZEL LUBRICATORS assure positive force feed lubrication for the protection of your valuable machinery. There's a model just right for your needs. Our field engineers are available for consultation.
WRITE FOR COMPLETE CATALOG
Manzel
LUBRICATORS • CHEMICAL FEEDERS • SLURRY PUMPS
273 BABCOCK STREET • BUFFALO 10, NEW YORK
A Division of Houdaille Industries Inc

Evaporation Test Cell. Bulletin 719 discusses the use of the Evaporation Test Cell, the only commercially available apparatus for determining evaporation losses of greases and low-viscosity lubricating oils used in sub-zero temperatures; and describes such features of the cell as its temperature control and air flow control accuracy, wide temperature operating range, and dual (oil/grease) usage. (Precision Scientific Co., LE-12/5, 3737 W. Cortland St., Chicago 47, Ill.)

High-Capacity Filter Design. A newly engineered, high-capacity simplified filter for diesel fuel and lube, pipelines, process liquids, water, gasoline, and aviation fuels is described in Catalog MK-170. This new filter is designed for flow rates up to 2000 gpm in a small space (2½ feet diameter by 4½ feet high) and to offer four degrees of filtration (50, 25, 10, and 5 microns) down to 1 micron. Fast, easy cartridge changes are main features of this design. Specifications, flow rates, and engineering drawings are included in this 4-page catalog. (Cuno Engineering Corp., LE-12/5, 4612 S. Vine St., Meriden, Conn.)

Silicone Rubber Products. Bulletin AD-147 describes the complete line of Garlock silicone rubber products that withstand high or low temperatures, resist sunlight, ozone, and aging; resist low-swell mineral oils at high temperatures, and possess good resistance to a large variety of other chemicals. Applications described include molded and extruded parts for appliance, automotive, and aircraft products, as well as for industrial seals. Inquiries for the new bulletin are invited from manufacturers who have sealing or gasketing conditions involving high heat, or where flexibility of sealing material at low temperatures is required. (Garlock Packing Co., LE-12/5, Palmyra, N. Y.)

Mathematical Calculation Charts. Two new mathematical charts developed by E. J. George, Sun Oil Co. engineer, and distributed exclusively by the Frederick Post



Railroads using a grease containing Moly-Sulfide on journal bearings have accomplished a notable reduction in HOTBOXES, because...

Moly-Sulfide Extends Effective Lubrication

when normal hydrodynamic oil film is wiped away

Hotboxes have been reduced materially in field tests by three leading railroads.*

Engineers of these roads are lubricating journal boxes with a supplemental grease containing Moly-Sulfide additive, which is applied direct to the journal during the normal servicing of the box.

The railroad industry pays an annual bill of about $90 million resulting from some 183,000 "hot boxes". The experience to date of these railroads indicates that Moly-Sulfide may provide a way to cut this expense substantially.

Moly-Sulfide appears to form a lubricating film on the journal and bearing. When a shock load or shearing action displaces the hydrodynamic film, the Moly-Sulfide film sustains effective lubrication until the petroleum film is restored.

This ability to extend effective lubrication is being tested by railroads in other critical applications, such as ball and socket joints of couplings, diaphragms, center plates, cylinder test cocks, traction gears and other parts of diesel locomotives, and on several points of car trucks.

You may obtain (1) more facts on how Moly-Sulfide functions as an additive, and (2) sources of railroad greases containing Moly-Sulfide by using the coupon below.

*Names on request.

Use the moly key ...to lubrication insurance

CLIMAX MOLYBDENUM

- Films on metal
- Low shear strength
- High film strength
- Non-Corrosive

Resists:

- heat
- cold
- water
- chemicals

Department 38

CLIMAX MOLYBDENUM COMPANY

500 Fifth Avenue, New York 36, N. Y.

Please send me the following:

Literature

- ☐ "Moly-Sulfide, Lubricant Additive"
- ☐ "Moly-Sulfide in Chassis Grease"
- ☐ "Moly-Sulfide Specification and Properties"

Lists of Sources for

- ☐ Railroad Greases
- ☐ Chassis Greases

Sample — One-ounce tube of Moly-Sulfide ☐

Name_____ Position_____

Company_____

Address_____

Solve LUBRICATION SPRAY APPLICATION PROBLEMS

Lincoln MistOmatic System

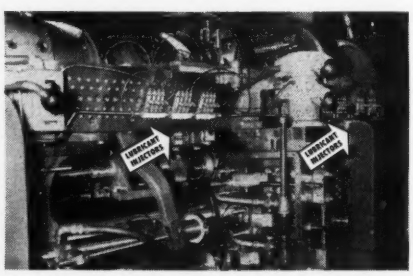
Lubricant mist automatically applied to open gears while, simultaneously, all other bearings are lubricated in seconds.

AUTOMATIC MIST LUBRICATION simultaneously with centralized closed bearing lubrication

New, exclusive Lincoln MistOmatic Spray Control Valve . . . designed for use with Lincoln power-operated Centralized Lubrication Systems! Dispenses controlled quantity of mist lubrication on open gears and chains, cams, rollers, eccentrics, slides and ways, circular saws and similar surfaces. Simultaneously, balance of machine bearings are *automatically* lubricated by the Centralized System injector circuit in seconds, while machine is operating.

Positive "mechanized maintenance" for automated machine groups and components

Lincoln Power-Drive Centralized Lubrication Systems automatically apply pre-measured quantities of viscous or fluid lubricants at pre-set controlled time intervals for individual machine units. Mechanical or electrical timing and control devices can be incorporated to suit individual machine requirements. Machine units in automated production lines can be interchanged without disturbing lubrication system.



Lincoln Pumping Unit supplies heavy-duty Way Oil to lubricant injectors shown above, serving 78 bearings, simultaneously each time System is cycled.

Send for new free Bulletins 806-R and 809

Lincoln **LINCOLN ENGINEERING COMPANY**
Division of The McNeil Machine & Engineering Co.
5743 Natural Bridge Avenue • St. Louis 20, Missouri

Co. under the name "Calculine," provide a convenient, economical tool that can be used for the same purpose as a slide rule or calculating machine. The charts, furnished on heavy 8½ x 11" card stock, consist of a log scale superimposed diagonally upon a log log grid. The Multiphase mathematical chart includes scales for multiplication and division, as well as those for obtaining directly the square root, cube root, and logarithm of a number. The multiplication and division chart has the same pattern, but without the log, square, and cube root curves. Both Calculine charts contain examples illustrating the various mathematical operations which can be performed. Values on the chart can be read directly without the use of a straight edge as required with a nomograph. An added feature of these charts is that the operator has a free hand to record values instantly as they are read. (Price 50c each or 2 for 85c; Frederick Post Co., LE-12/5, 3666 N. Avondale Ave., Chicago 18, Ill.)

Bibliography on Non-Metallic Bearings. "ESL Bibliography No. 6" is an annotated bibliography of 101 selected references to the literature of the past twelve years covering all aspects of non-metallic bearings such as their manufacture, design, properties, wear, lubrication, performance, testing and applications, particularly of bearings made of rubber, wood, laminated phenolic plastics, resin-impregnated cotton fabric, micarta, and nylon. Applications discussed are for rolling mills, marine propeller shafts and rudder posts, automatic presses, axle bearings for railroad rolling stocks, and agricultural machines. (Price $2.00, Engineering Societies Library, 29 W. 39th St., N. Y. 18, N .Y.)

Triplex High-Pressure Pumps. Bulletin P-55 covers the application of the Gaulin horizontal Triplex pump in ten different industries, complete with illustrated data on the construction and operation of the mechanism. It shows five basic cylinder designs which meet the requirements of

all pumping applications — ranging from a completely sanitary design for food products to one suitable for handling extremely abrasive products. A specification chart is included, as well as graphs covering machine selection and typical power curves. (Manton-Gaulin Mfg. Co., Inc., 44 Garden St., Everett 49, Mass.)

"The Diamond Tool Industry in 1955." As in previous years, the Industrial Diamond Information Bureau has again compiled a survey of the diamond tool industry, dealing with various scientific and technical aspects. While no entirely new developments could be traced, practically all branches of the industry made important advances during the past year. Based mainly on the Bibliography of Industrial Diamond Applications, this 12-page survey is subdivided into 16 main groups; about 200 references are quoted. (Industrial Diamond Information Bureau, 34/35 Holborn Viaduct, London EC1, England.)

(New Products, from p. 299)

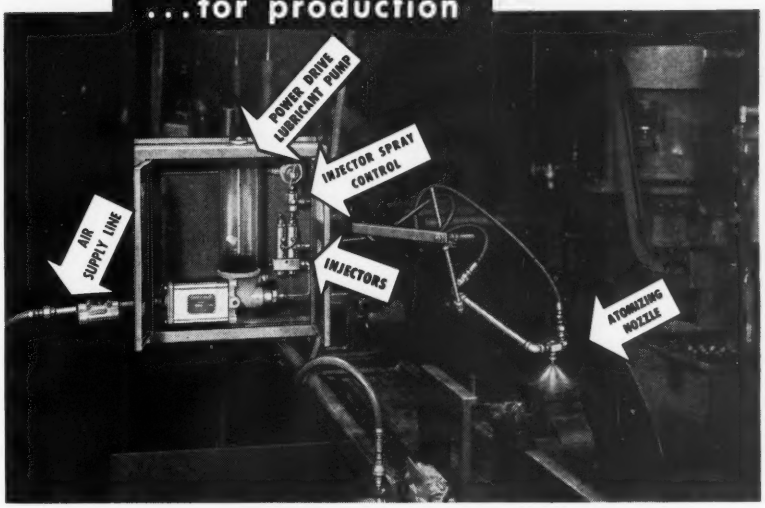
nent, bar stock bronze screen has been redesigned to include the added features of magnetic separation, making use of a flat magnetic field onto which the liquids are diffused. This new principle of design uses the force of gravity to assist the magnetic field. The efficiency of the magnetic field is even further increased: the large, powerful magnet area of No. 5 Alnico magnets gives twice the width of field, and permits lower flow velocity. The Up-Flo action carries the liquids that have been exposed to the magnetic field up through the permanent .004" bar stock screen to remove particles such as abrasives which do not respond to the magnets. The liquid flows into a storage tank where settled particles smaller than .004" are removed by chain-driven flight. Up-Flo Filters are available without magnets for non-ferrous metal applications. (Industrial Filtration Co., Dept. UM-395, Lebanon, Ind.)

Drum Dolly. Designed for vertical handling of open-end drums,

Speed Up ASSEMBLY LINE SPRAY APPLICATIONS

Lincoln MistOmatic System

...for production



MistOmatic spray control arranged alongside production line automatically applies lubricant mist to gear box components.

AUTOMATIC ASSEMBLY LINE APPLICATION of paint, glue, grease, oil

Lincoln pioneers a major step toward complete assembly line automation... to boost your profits! The MistOmatic Spray is being used through industry—with great success—for production line spraying of grease, oil, paint, glue and similar materials. Quantity of material sprayed, timing and pattern of spray, adjusted to your needs.

These valve assemblies can also be used *without* spray attachment for automatic application of various materials to production components, and for automatic application of such fluids as die lubricants. Get complete details now!

Send for these new Free Bulletins

Information and specifications on how you can "build in" Automatic Maintenance and Automatic Spray applications for your *automated lines... machine tools... production equipment... materials handling equipment!* Write today!

Lincoln LINCOLN ENGINEERING COMPANY
Division of The McNeil Machine & Engineering Co.
5743 Natural Bridge Avenue • St. Louis 20, Missouri

The feather-touch with **DYNAMITE ACTION!**

MORE EFFECTIVE THAN EVER —MARLA AERO SPRAY PENETRATING OIL GIVES YOU THE ADVANTAGES OF:

1. SPRAY

Assures penetration, with pressure, to the most hard to get at objects. Shoots a stream three feet if needed.

2. SPEED

Always ready at the touch of a button. The fastest acting non acid, non alkali penetrating oil known or money back.

3. ECONOMICAL

Spray container eliminates wasted surplus and time in application. Cannot leak or spill.

4. HANDY

Carried easily and is always ready for use. No chance for ingredients to weaken by exposure to air from a misplaced cap.

5. VERSATILE

Marla Spray Penetrating Oil is used to free the most corroded bolts, screws, pipe threads, bearings, bushings, pulleys, manifolds, valve guides, locks or any other stuck together metal parts.

Industrial Packaging & Price Schedule
F.O.B. St. Louis, Mo.

Case of Six—12-ounce Cans ..... $ 9.00
Case of Twelve—12-ounce Cans 17.40

MANUFACTURED
AND
UNCONDITIONALLY GUARANTEED
BY

ROTHLAN CORP.

3618 Laclede Ave., St. Louis 8, Mo.

Specialists in Fine Penetrating Oil
for Over Thirty Years

the new Morse Drum Dolly No. 13 assures safety by the deep lip which holds the drum securely in place. Durability is assured by the cross members which give added strength for load capacities up to 700 lbs. Built of 2½" steel for long life, the dolly is 24" in diameter with an overall height of 6½"; four 3" diameter steel swivel casters make the dolly easy to get into small areas. (Morse M anufacturing Co., LE-12/5, 755 W. Manlius St., E. Syracuse, N. Y.)

Non-Flammable Solvent. "Immunol," a neutral, non-toxic, nonflammable solvent that cleans, degreases, and rustproofs all metal surfaces safely and effectively in one operation, can be applied by any method now in common use to clean anything from small parts to heavy machinery. Mixed with hot or cold tap water, the solvent is said to be superior to carbon tetrachloride, trichlorethylene, kerosene, mineral spirits, and gasoline; and it quickly carries off oils, soils, or foreign matter, leaving a protective rustproof coating. Only a few ounces of the solvent per gallon of water are required to produce a gallon of solvent which can be used over again for many applications once the foreign matter has been removed. Immunol can be used: in vapor degreasing units; for improving alkali cleaners; as a rust preventive; for the final rinse after plating; for tumbling operations: for machine shop applications; to increase tool life and improve machining operations; to remove gum deposits in oil-operated hydraulic and lubricating systems; and for quenching and hydrostatic testing. (Harry Miller Corp., LE-12/5, 4th & Bristol Streets, Philadelphia 40, Pa.)

Chemical Packing. A newly-developed fiber used in "405" mechanical packing, offers greater corrosive resistance and service life. This packing is a braid over braid of glass and Teflon—two of the most inert fibers. The fine pure Teflon fibers braided over a core of glass fibers and impregnated with Teflon presents a soft pliable low-friction packing that is excellent for use on centrifugal as well as reciprocating and static applications. Concentrated acids such as sulphuric, nitric, sodium hydroxide, aqua regia; alkalies, and practically all solvents simple or complex are easily handled. (Abbott & Biddle, LE-12/5, 2417-17 Federal St., Philadelphia 46, Pa.)

Waterless Skin Cleanser. A new refillable bench dispenser containing waterless skin cleanser for industrial use is said to conserve man-hours by providing each worker with an individiual hand cleanup facility. The dispenser is unbreakable polyethylene and carries an imprint space for applying a serial number when the unit is assigned to a worker. Refilling is done at the tool crib or other central area from a bulk container. The waterless skin cleanser removes paint, grease, and other industrial soil except dry lacquer. A greaseless residual of lanolin, glycerine, and hexachlorophene is claimed to aid in prevention of dermatitis. (Hammons Products, Inc., LE-12/5, Fort Wayne, Ind.)

Lubrication in the News

S.R.I. to Evaluate Moly-Sulfide Chassis Grease. Southwest Research Institute, San Antonio, Texas, will conduct a road study for Climax Molybdenum Company evaluating the effect of incorporating Moly-Sulfide additive in chassis grease.

The program, expected to require twelve months, will consist of road tests to determine the effectiveness of chassis grease in various vehicles under their normal operating conditions. Half the vehicles of each type used in the test will be lubricated with commercial chassis grease, the other half with the same chassis grease in which 3% Moly-Sulfide Pure has been dispersed. Wear

will be determined by before-and-after weight comparisons, dimensional measurements and surface inspection of key parts. In the final analysis, these data will be considered in conjunction with service logs and driver reports on squeaks, ease of steering, and other pertinent observations. Thirty vehicles will travel a total of 1,500,000 to 2,225,000 miles in the road test. Eight city buses, twelve tractor-trailers in long haul service, and ten police cars will be used.

Prior to testing, each vehicle will be inspected to insure that wheel alignment, steering, suspension, drive shaft and brake shoes meet specified standards. In addition, critical parts such as wheel bearings, king pins and bearings, ball joints, brake actuating cams, bushings, shackle pins and bushings, tie rod ends and steering linkage will be replaced with new parts. These will be weighed and measured before installation. During the test, all will be lubricated and inspected at regular mileage intervals. At the conclusion, the parts will be removed, cleaned and again weighed and measured to determine wear.

Drivers of the test vehicles will report daily on such factors as weather conditions, vehicle complaints, road surface conditions, and mechanical breakdowns. Driving procedure for the automobiles and buses will not vary from normal operational practices. However, the tractor-trailers will be routed so that two or more trucks, preferably one with and one without the additive, will travel over the same route.

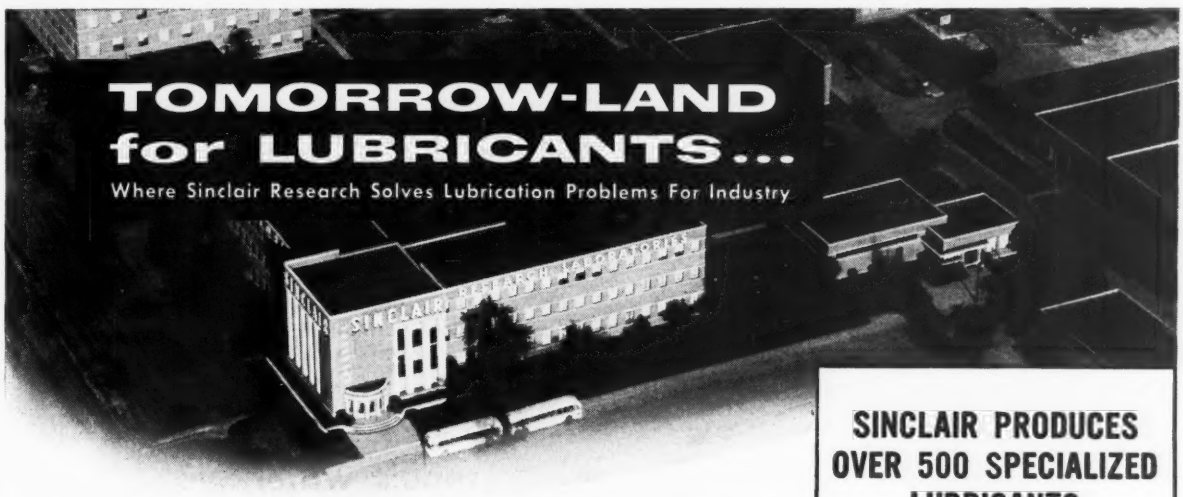
"Antioxidants for Greases." Amines are better inhibitors of oxidation in greases than any other types tested in an Army Ordnance Corps research program to develop compounds for this purpose. This is the conclusion of researchers in Interim Report No. 2 of the program which has just been released to industry through the Office of Technical Services, U. S. Department of Commerce.

Outstanding among the amines are the phenylenediamines. The sulfur compounds used in the study did not show anything exceptional as inhibitors, but three of the substituted phenols were able to inhibit oxidation in some types of greases for more than 500 hours.

Forty-five compounds were tested in greases at 210° F., and those which were effective at this temperature were also tested at 250°. Only six of the inhibitors tested in the program would inhibit oxidation for 500 or more hours at 250°. All of them were tested in lithium soap mineral oil greases, and a number in calcium and lithium-calcium soap mineral oil greases. Copper corrosion tests were run on all successful inhibitors and the acidity or basicity of the grease was determined.

This report, PB 121017 "Antioxidants for Greases," S. F. Calhoun, Rock Island Arsenal Laboratory, U. S. Army, Nov. 1955, may be ordered from OTS, U. S. Department of Commerce, Washington 25. It contains 34 pages, price $1.

Statement on Compatibility Testing of Lubricating Greases. ASTM Committee D-2 on Petroleum Products & Lubricants has approved the following statement



Located at Harvey, Illinois, is one of the most extensive installations of its kind in the world—Sinclair Research Laboratories. These facilities are an important part of Sinclair's investment in the future. Here is where Sinclair engineers and chemists work to develop new products and improve the quality of existing ones. At these famous laboratories were developed the Sinclair lubricants now solving difficult problems in all branches of industry. If you have a special lubrication problem, write today to Sinclair Refining Company, Technical Service Division, 600 Fifth Avenue, New York 20, N. Y.

SINCLAIR PRODUCES OVER 500 SPECIALIZED LUBRICANTS for

TURBINES
DIESEL ENGINES
PLANT MACHINERY
METAL WORKING
AUTOMOTIVE EQUIPMENT
and many other applications

SINCLAIR REFINING COMPANY

prepared by its Technical Committee "G" on Lubricating Grease:

"Compatibility of lubricating greases implies compatibility in service. Owing to the complexity of service problems, there is no single test which can be used to satisfactorily evaluate compatibility in general.

"Present ASTM methods, such as those for Dropping Point, Worked Penetration, and Leakage Tendencies of Automotive Wheel Bearing Greases, may be use to test mixtures of greases as well as to test individual greases. Results obtained on such mixtures, as compared to results on the unmixed component greases, are indicative of the compatibility of the mixtures. However, simple bench tests such as these must be correlated with a particular set of service conditions before a valid estimate of compatibility in such service can be achieved."

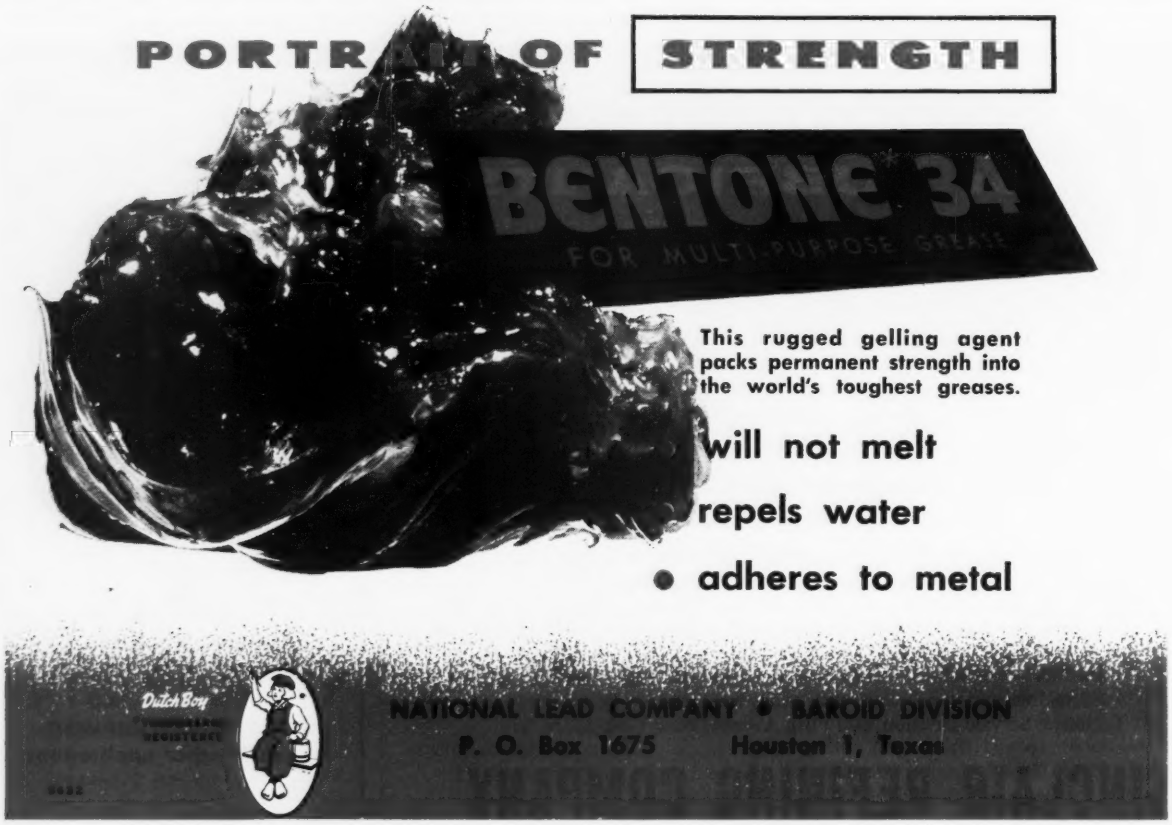
LUBRICATION RESEARCH ASSISTANTSHIP

Openings for graduate study with part-time employment assisting research group investigating oil film "whip," etc., in high-speed plain bearings. Start Feb. or Sept. Write Prof. G. DuBois, Mech. Engrg., Cornell Univ., Ithaca, N. Y.

(Lube Lines, from p. 303)

latest developments. This material possesses inherent slipperiness, chemical stability, and resistance to high temperature. Its lubricating ability is so pronounced as to render it well suited for usage in automotive suspension joints and other chassis parts. Used here as a facing or lining fabric for the metallic surfaces, this material is said to be so durable and protective that it will last the lifetime of the part without lubrication or maintenance. There is a definite trend in automotive circles to get away from metal-to-metal contact in chassis assembly on parts which are subject to intermittent motion, to such an extent that some lubrication guides for late model cars show only front end requirements (9 fittings, for example); all formerly lubricated rear end shackles, springs, etc., being today mounted on non-metallic materials.

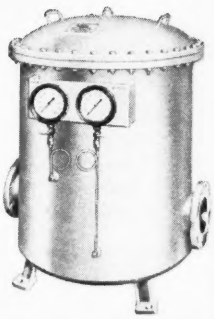
This activity in the field of dry lubrication is of definite interest to the lubrication engineer. It gives him added assistance in developing design, assembly, and maintenance features on key or critical operations. This will relieve him of worry and enable him to concentrate more effectually on servicing his heavy-duty, high-speed, high-load production machinery, which can operate properly only when protected by petroleum-base lubricants. There is an inherent cooling effect which accompanies fluid lubricants in circulation. It is as much a function today in the lubrication of precision machinery as the lubricating ability of the oil itself.


PORTRAIT OF STRENGTH
BENTONE 34
FOR MULTI-PURPOSE GREASE
This rugged gelling agent packs permanent strength into the world's toughest greases.
will not melt
repels water
• adheres to metal
Dutch Boy
NATIONAL LEAD COMPANY • BAROID DIVISION
P. O. Box 1675 Houston 1, Texas

COMPLETE FILTRATION COVERAGE

there's a Commercial Filters unit engineered for your filtering job...

Fulflo FILTERS

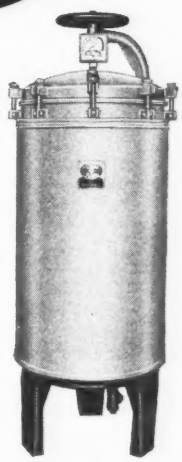


Fulflo Filters provide optimum clarity at ultra-high flow rates. For all industrial fluids—including oils, liquid fuels, chemicals, water, compressed air and various gases. Sizes to handle flow rates up to 1,600 gpm. Pressures to 4,000 psi.

Fulflo Filters feature Honeycomb Filter Tubes, the "precision controlled density" element that filters every drop again and again to give you microscopic clarity. Choice of cotton, acetate, nylon, orlon, dacron, dynel or glass fibres.

Standard models available in steel, stainless steel, rubber lined steel or nickel-plated brass. Custom models engineered to special requirements.

Honan-Crane FILTERS



Honan-Crane Filters offer "clean oil" filtration in diesel, turbine, hydraulic, metalworking and quenching operations. Bulk refill models provide depth filtration with cellulose medium for additive oils and Cranite (fullers earth) medium for straigth mineral oils. Multi-cartridge models feature six different types of cartridges that may be used interchangeably depending on type and degree of filtration desired. Flo-Pac models, installed in line, handle flow rates up to 900 gpm. All have quick-opening covers for ease in changing refills.

other CFC products

Purivac Insulating Oil Conditioners
High Pressure Hydraulic Filters
Magnetic Separators
Plating Filters
Coolant Clarifiers
Oil Burner Filters
Compressed Air Filters
Dri-Pure Water-Oil Separators
Pre-Coat Filters
Water Filters
Beverage Filters
Pharmaceutical Filters
Automatic Tubular Conveyors

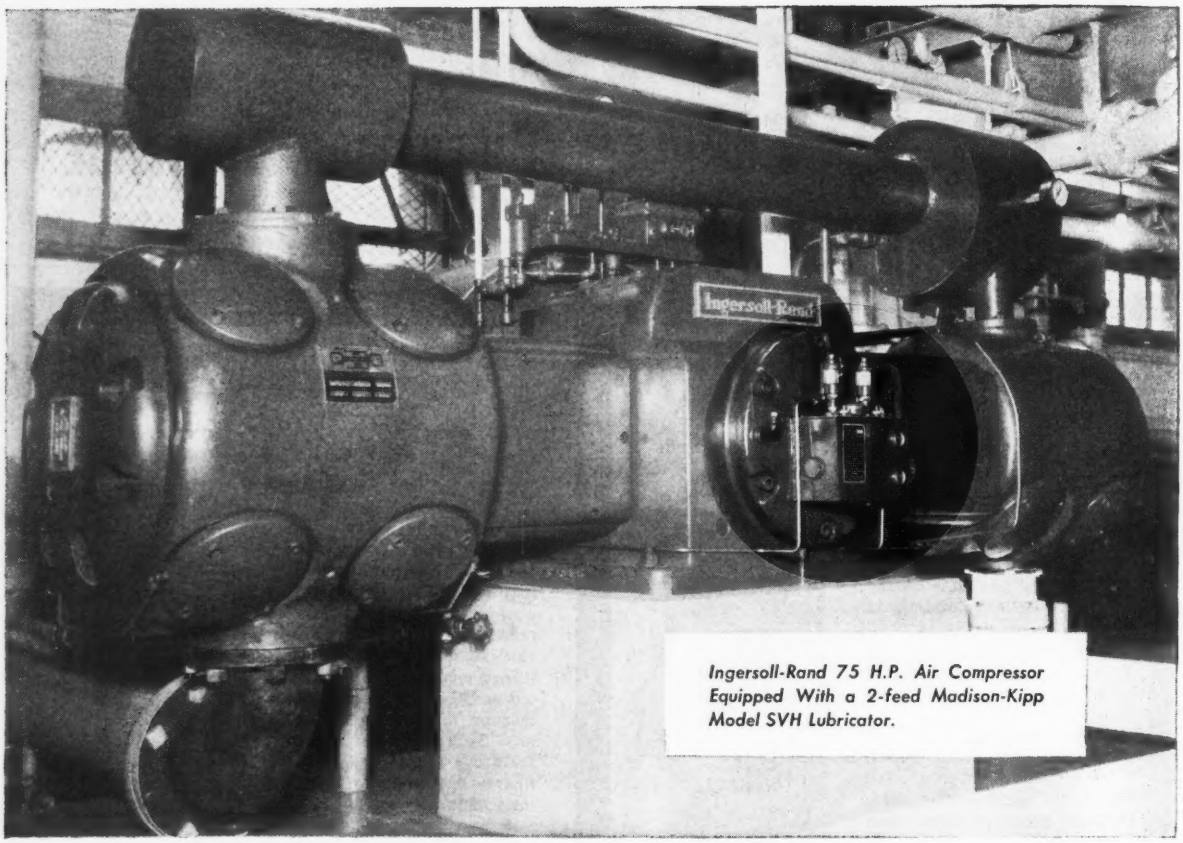
FILTERS Michiana

Diesel and gasoline engines get complete protection against the damaging effects of dirty oil with Michiana Lube and Fuel Oil Filters. Designed for low cost filtration and proven in thousands of installations. "Throw-away" or repackable filter elements. Available in a wide range of sizes and models.

Write for literature or engineering help covering your filtration problem.

COMMERCIAL FILTERS CORPORATION

MELROSE, MASSACHUSETTS • LEBANON, INDIANA



Ingersoll-Rand 75 H.P. Air Compressor Equipped With a 2-feed Madison-Kipp Model SVH Lubricator.

Machines of great performance use the most dependable oiling system ever developed

MADISON-KIPP

Fresh Oil . . . by the measured drop, from a Madison-Kipp Lubricator is the most dependable method of lubrication ever developed. It is applied as original equipment on America's finest machine tools, work engines and compressors. You will definitely increase your production potential for years to come by specifying Madison-Kipp on all new machines you buy, where oil under pressure fed drop by drop can be installed. There are 6 models to meet almost every installation requirement.

kipp

MADISON-KIPP CORPORATION
223 WAUBESA STREET • MADISON 10, WIS., U.S.A.

• Skilled in Die Casting Mechanics • Experienced in Lubrication Engineering • Originators of Really High Speed Air Tools

Patent Abstracts

(Compiled by Ann Burchick, Aluminum Co. of America.)

Lubricant, Patent No. 2,721,181 (F. I. L. Lawrence, R. K. Smith & M. J. Pohorilla, assignors to Kendall Refining Co.) A lubricant consisting essentially of an oil of lubricating viscosity containing an organo-boron composition produced by passing a free-oxygen containing gas through a normally liquid paraffinic petroleum fraction having a boiling point in the range of about 350 F. to about 800 F., maintained at a temperature within the range of about 305 F. to about 385 F.; there being available in said fraction from about 1 to about 3 chemical equivalents of an acid, selected from the group consisting of ortho-boric acid and meta-boric acid per mole of paraffinic hydrocarbon; said gas being passed through said fraction at a rate requisite to provide not more than about 0.6 cubic feet of oxygen per hour per gallon of said fraction; to produce a crude reaction product containing at least about 0.2% by weight of chemically combined boron, said composition being present in an amount sufficient to inhibit oxidation of said oil fraction.

Method of Blending Oils and the Resulting Product, Patent No. 2,721,803 (W. W. Ginn, assignor to Vejin, Inc.) The method of combining at least two fatty triglycerides which are not mutually soluble and consequently do not fully dissolve together, one of said triglycerides having relatively high titre and relatively low iodine value, the other having relatively low titre and relatively high iodine value, said method comprising intermixing said fatty triglycerides in the presence of substantially 5 to 25 per cent of a member of the class consisting of rape-seed oil and rice oil.

Organo-Metal Complexes and Lubricating Oils Containing Them, Patent No. 2,721,843 (J. F. Palmer, Jr., assignor to Monsanto Chemical Co.) As a new composition of matter, the oil-soluble organo-metal complex obtained upon heating, with the elimination of water, substantially equimolecular proportions of an oil-soluble basic alkaline earth metallo hydrocarbon sulfonate, carbon disulfide and a dialkyl amine wherein the respective alkyl groups contain at least 5 carbon atoms.

Lithium Soap-Synthetic Base Instrument Grease, Patent No. 2,721,844 (C. H. Culnane & J. P. Dilworth, assignors to The Texas Co.) A lubricating grease composition consisting essentially of an oleaginous liquid base as the predominant constituent thickened to a grease consistency by about 12 to 20 per cent by weight based on the weight of the composition of a lithium soap of a soap-forming fatty material, said soap-forming fatty material consisting of a major proportion by weight of a hydroxy soap-forming fatty material selected from the group consisting of hydroxy stearic acid and hydroxy stearic acid glyceride, and a minor proportion of a saturated soap-forming non-hydroxy fatty acid, said oleaginous liquid base consisting of an oil-soluble high-boiling aliphatic dicarboxylic acid diester having a viscosity within the range from about 6 to 10 centistokes at 100 F., selected from the group consisting of branched chain diesters of adipic, azelaic and sebacic acids with C_5-C_8 alcohols, and about 5 to 8 per cent by weight based on the weight of the composition of a mineral lubricating oil having a viscosity within the range from about 14 to 30 centistokes at 100 F., said grease having an ASTM worked penetration in the range 260-330 and a low temperature torque test below 5 seconds per revolution at —100 F.

Metal Soap Grease Containing Alkaline Earth Metal Alkyl Phenol Sulfide, Patent No. 2,721,845 (J. P. Dilworth, C. H. Culnane & H. V. Ashburn, deceased, assignors to The Texas Co.) A lubricating grease composition comprising as the essential constituents an oleaginous liquid lubricating base of which at least the major proportion is a high boiling liquid aliphatic dicarboxylic acid ester, about 10-30% by weight of a lithium soap of a saturated soap-forming fatty material, said grease normally being corrosive to copper, and from 0.25 to 5% by weight based on said composition of barium diamyl phenolate sulfide in sufficient proportion to enable said grease composition to pass the copper corrosion test of U. S. Army specification 2-134.

Flushing Oil Composition, Patent No. 2,721,846 (J. F. Lyons & T. C. Heisig, assignors to The Texas Co.) A high flash point flushing oil characterized by rust-proof, antioxidant and drying properties which comprises a mineral lubricating oil as a major constituent, 0.001 to 2 per cent by weight of an oil-miscible aliphatic dicarboxylic acid having at least 10 carbon atoms, 0.0001 to 1 per cent by weight of an oil-miscible aliphatic acid phosphate containing at least 10 aliphatic carbon atoms, 0.05 to 3.0 per cent by weight of an oil-miscible alkylated phenol and 4 to 10 per cent by weight of tripropylene glycol monomethyl ether.

Lubricating Oil Additives and a Process for Their Preparation, Patent No.

MARLA

OPEN GEAR SPRAY LUBRICANT

Use on all Gears not running in Oil

Absolutely Nothing Else Like it!

OUTLASTS ORDINARY LUBES 5 to 1

Sticks to Metal

1. **ECONOMICAL** — Spray container reduces lubrication time. Long lasting film. One can covers approximately 25 sq. ft. of surface with no waste.
2. **HEAVY DUTY** — The finest extreme pressure adhesive lubricant there is for open gears.
3. **EASY-TO-USE** — No fuss . . . no muss. Ease of application encourages and assures complete lubrication of open gears.
4. **CLEAN** — No drip . . . no throw off . . . no clean up of excess lubricant. Will not drip in hot or steamy areas.
5. **SPRAY** — Assures perfect lubrication even to the most hard-to-get-at areas.
6. **HANDY** — Marla Spray Lubricant can be carried easily and is always ready for use. Eliminates the brush, paddle or any preheating.
7. **VERSATILE** — A superior lubricant also for cams, reciprocating actions, mono rails, guides, chains, sprockets and cables.

Prices F.O.B. Your Plant

Case of Six—12-ounce Cans. . . . $10.74

Case of Twelve—12 ounce Cans. 21.00

MANUFACTURED
AND
UNCONDITIONALLY GUARANTEED
BY

ROTHLAN CORP.

3618 Laclede Ave., St. Louis 8, Mo.

★ ★ ★ USE ★ ★ ★

CRESOL

ADDITIVES

★ ★ ★ ★ ★ ★ ★ ★

in the preparation of:

Cutting Oils
Drawing Oils
Grinding Oils
Metal Working Oils
Engine & Heating Fuels
Rust Preventives

For
Exceptional Performance
at Low Cost
use

- CRESOL Z-1, for EP Gear Oils, Cutting Oils, Drawing and Stamping Oils
- CRESOL Z-2, for Cutting Oils, Grinding Oils
- CRESOL Z-3, for EP Lubricants, Drawing Compounds
- CRESOL Z-4, for Soluble Drawing Oils and Cutting Oils
- CRESOL Z-5, Oxidation Inhibitor for Lubricating Oils
- CRESOL Z-7, for Automatic Transmission Fluids
- CRESOL Z-51, for Rust Preventives (Oil and Solvent Type), Lubricity Agent for Lubricating Oils, Fatty Oil Replacement
- CRESOL 22-C, Engine and Heating Oil Additive to prevent carbon deposits

Samples, and suggested formulae for general or specific applications, available upon request.

★

BURNS LABORATORIES, INC.
514 WEST WYOMING STREET
INDIANAPOLIS, IND.

2,721,877 (A. H. Popkin & J. F. Black, assignors to Esso Research & Engineering Co.) In a process for the formation of lubricating oil additive materials which comprises copolymerizing (1) about 98 to 60% by weight of a substantially neutral ester prepared by esterifying (a) a material of the class consisting of alpha, beta-unsaturated polycarboxylic acids and their anhydrides with (b) substantially saturated primary aliphatic alcohol containing in the range of 8 to 18 carbon atoms per molecule with (2) about 2 to 40% by weight of a low molecular weight vinyl ester in the presence of a peroxide catalyst, the improvement which comprises carrying out said esterification in the presence of a stoichiometric excess of from 2.5% to 15% by weight of said alcohol and copolymerizing said neutral ester with said vinyl ester in the presence of said excess of alcohol.

Strong Acid as a Polymerization Modifier in the Production of Liquid Polymers, Patent No. 2,721,878 (A. H. Popkin, assignor to Esso Research & Engineering Co.) In a process for the formation of lubricating oil additive materials which comprises copolymerizing (1) a substantially neutral ester of (a) substantially saturated primary aliphatic alcohol containing in the range of 1 to 18 carbon atoms and averaging about 7.5 or more carbon atoms per molecule and of (b) a material of the class consisting of alpha, beta-unsaturated polycarboxylic acids and their anhydrides with (2) a low molecular weight vinyl ester in the presence of a peroxide catalyst, the improvement which comprises the use of about 0.02% to 5.0% by weight, based on the weight of the monomers, of a strong acid as a copolymerization modifier.

Phosphoric Acid Esters of Diethylene Glycol Ethers & Lubricants Containing the Same, Patent No. 2,723,237 (J. P. Ferrin, assignor to The Texas Co.) A lubricant comprising a major portion of a mineral oil of lubricating characteristics and 0.5 to 25 weight per cent tributyl carbityl phosphate, said carbityl phosphate acting as a pour point depressant in said lubricant.

Preparation of Polymerization Products from Propene & Pentene Oxides, Patent No. 2,723,294 (G. J. Benoit, Jr., assignor to California Research Corp.) Process of preparing polymeric materials useful as synthetic lubricants, which comprises subjecting to polymerization temperatures and pressures in the presence of an alkaline catalyst, an aliphatic monohydroxy alcohol effective to initiate the polymerization reaction, about 70 to 90 mol per cent propene oxide, and about 10 to 30 mol per cent pentene oxides, of which pentene oxides not more than about 5 mol per cent, and 15 mol per cent, based on the total propene-pentene oxide content, is, respectively, 2-methyl--2,3-epoxybutane, and material selected from the group consisting of 2,3-epoxypentane, 2-methyl-1,2-epoxybutane and 1,2-epoxycyclopentane, said catalyst being present in an amount expressed by the ratio of about 1 mol of said alkaline catalyst to about 700 to 100 mols of said propene oxide and pentene oxides, and said alcohol being present in an amount of about 1 mol to about 8 to 200 mols of the propene-pentene oxide content.

Rust Preventive Compositions, Patent No. 2,724,654 (W. C. Howell, Jr. & W. E. Waddey, assignors to Esso Research & Engineering Co.) A rust preventive composition comprising about 75 to 98% by weight of volatile hydrocarbon solvent having a boiling point below about 500 F., about 1 to 15% by weight of a viscous propane precipitated resin from Pennsylvania oil residuum, and about 1 to 10% by weight of a monooleate ester of a polyhydric alcohol.

Mineral Oils Containing Alkoxyalkylolamine Epichlorhydrin Condensation Products, Patent No. 2,724,694 (E. J. Troianello, assignor to American Cyanamid Co.) A self-emulsifying mineral oil composition comprising mineral oil having dissolved therein a minor quantity not less than 2.5% by weight of the reaction product obtained by heating 0.05 to 0.5 mols of epichlorhydrin with the condensation product of 1 mol of a primary alkylamine of 12-18 carbon atoms with 2 to 10 mols of combined ethylene oxide.

Preparation of Emulsifiers for Producing Soluble Oil, Patent No. 2,724,697 (M. R. Lipkin, assignor to Sun Oil Co.) Method of forming an acidic partial oxidation product containing mahogany sulfonates and suitable for use in preparing soluble oil which comprises treating a petroleum oil boiling mainly above 450 F. with a sulfonating agent under sulfonating conditions, separating sludge from the sulfonated stock, neutralizing the sulfonated stock with an alkaline-reacting alkali metal compound, and treating the neutralized stock in liquid phase with a free-oxygen containing gas under conditions, including a temperature above 110 C., effecting partial oxidation to carboxylic acids.

Lubricating Oil Anti-Foaming Agent, Patent No. 2,724,698 (A. R. Kittleson, assignor to Esso Research & Engineering Co.) A liquid oil composition having a normal tendency to foam under conditions of agitation and containing a minor proportion, sufficient to reduce said tendency substantially, of a substantially oil-insoluble stably dispersed nitrogen-containing polyneric condensation product of viscous oil consistency obtained by mixing substantially equimolar proportions of di-t-butoxydiamino silane and ethylene glycol at ordinary temperatures until a spontaneous reaction and NH_3 evolution takes place and until said evolution substantially ceases.

Stabilized Mineral Oils and Method of Preparation, Patent No. 2,725,345 (Kurt Binovic & Robert Dupas, assignors to Esso Standard Societe Anonyme Francaise). An oil composition of high oxidation resistance comprising a mineral base oil fraction of insulating-lubricating oil viscosity grade containing 0.01 up to 1% by volume of a propane deasphalted residual oil from the distillation of crude petroleum.

Lubricating Oils Containing Hydroxy and Alkoxy-Metal Oxyarylalkyl Amines, Patent No. 2,725,357 (H. D. Kluge & F. W. Moore, assignors to The Texas Co.) A lubricating composition comprising a mineral lubricating oil containing about 0.1 to about 0.5 per cent by weight of N,N'-bis(2-alkoxymetaloxy-5-alkylbenzyl)-1, 2-diaminoethane, wherein the metal is selected from the group consisting of alkaline earth metals and zinc, the alkoxy group is a C_1 to C_5 alkoxy group and the alkyl group is a C_5 to C_{30} alkyl group.

Lubricating Oils Containing Hydroxy Metal Oxyarylalkyl Amines, Patent No. 2,725,358 (H. D. Kluge & F. W. Moore, assignors to The Texas Co.) A lubricating composition comprising a mineral lubricating oil containing about 0.1 to about 5.0 per cent by weight of a basic metal salt of an N,N'-bis(2-hydroxy-5-alkylbenzyl)-1, 2-diamino ethane, wherein the metal is selected from the group consisting of magnesium and zinc and the alkyl group is a C_5 to C_{30} alkyl group.

Lubricating Oil Composition, Patent No. 2,725,359 (D. Harman, R. C. Morris & H. Diamond, assignors to Shell Development Co.) A composition of matter comprising a major amount of a mineral lubricating oil and a minor amount sufficient to inhibit oxidation of said hydrocarbon.

Non-Corrosive Lubricant Composition, Patent No. 2,726,208 (R. E. Karil & A. R. Sabol, assignors to Standard Oil Co.) A composition comprising a major proportion of an oleaginous lubricant vehicle and from about 0.1% to about 10% of the oil-soluble salt complex obtained by reacting at a temperature of from about 50 F. to about 210 F. an oil-soluble metal salt of a neutralized phosphorus sulfide-hydrocarbon reaction product with a water-soluble polyvalent metal salt of a low molecular weight aliphatic saturated carboxylic acid of 1 to about 4 carbon atoms, said water-soluble metal salt being used in an amount of from 0.1 to 3.0 equivalents of the polyvalent metal for each metal equivalent of the neutralized phosphorus sulfide-hydrocarbon reaction product and dehydrating the resultant reaction product at a temperature of from about 250 F. to about 350 F. while blowing with an inert gas.

The Sight Glass

Editor's Note: With this issue a new feature is introduced, **"The Sight Glass."** In this and succeeding issues of the journal The Sight Glass highlights some of the important articles which will appear in future issues of Lubrication Engineering so that the reader will not miss any new developments in our rapidly expanding field. Just as the sight glass is used in the lubrication system to show the regulation and flow of lubricants, the new feature will show the articles being processed for publication in the journal.

In Coming Issues!

Laboratory Evaluation of the Resistance to Oxidation of "R & O" Industrial Oils

Unsuspected correlation exists between two dissimilar oxidation stability tests, a highly controversial area in evaluating lubricating oils, and a test method which is easier, less time consuming, and cheaper is described. Forty oils were tested to verify the accuracy and correlation of the two methods described and reconfirmed with the testing of an additional twenty-three individual proprietary products, selected at random, and evaluated by both methods.

Studies of Formation and Behavior of an Extreme-Pressure Film

Gears lubricated with a mineral oil compounded with dibenzyl disulfide containing radioactive sulfur, S^{35}, were operated under controlled conditions. The formation and behavior of the resultant sulfur-containing film on the load-bearing surfaces have been studied, using the beta particles from the sulfur as a means of detection of the film and measurement of its thickness.

Organization of a Plant Lubrication Program — III

Third and final paper in the series which show how the proper selection and application of lubricants materially reduce maintenance costs and decrease productive downtime.

For information that will show you how

UCON
Brand
synthetic fluids and lubricants

can do a job *better* for you.

- ☐.....Hydraulic fluids
- ☐.....Safety hydrolubes
- ☐.....Gear lubricants
- ☐.....High-temperature lubricants
- ☐.....Low-temperature lubricants
- ☐.....Rubber lubricants
- ☐.....Packing lubricants
- ☐...Compressor and Pump lubricants
- ☐.....Lift-truck lubricants
- ☐.....Metal-working fluids
- ☐.....Heat-transfer fluids
- ☐.....Grease components
- ☐.....Textile lubricants
- ☐.....Defoamers and De-emulsifiers
- ☐.....Cosmetic oils
- ☐.....Ink and dye diluents
- ☐.....Leather softeners
- ☐.....Solvents and Plasticizers
- ☐.....Chemical intermediates

Better yet! Give us the specific requirements for your job. We'll give you more information on how UCON fluids and lubricants can help you.

CARBIDE AND CARBON CHEMICALS

CARBIDE AND CARBON CHEMICALS COMPANY

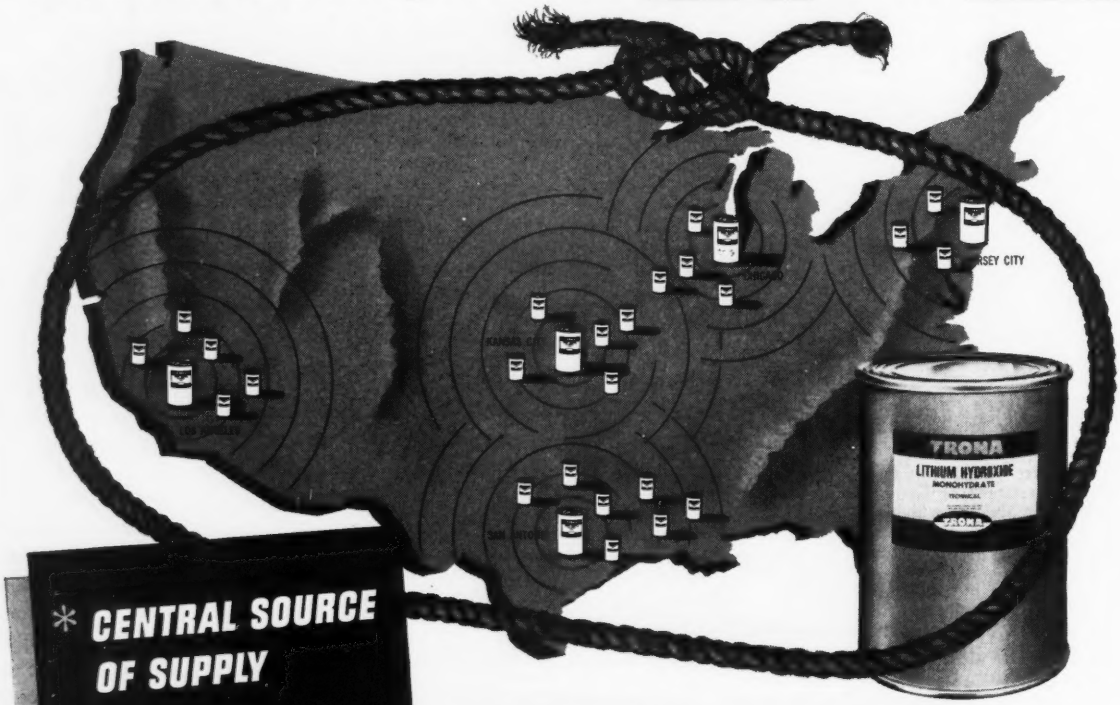
A Division of
Union Carbide and Carbon Corporation UCC
30 East 42nd Street New York 17, New York

"Ucon" is a registered trade-mark of UCC.

TRONA† LITHIUM HYDROXIDE

FOR MULTI-PURPOSE GREASES

...an essential product—tied in with service



* CENTRAL SOURCE OF SUPPLY
* STRATEGIC WAREHOUSING
* BETTER DELIVERIES

TRONA

GREASE MANUFACTURERS: There are three good reasons why Trona† should be your prime source of supply of lithium hydroxide monohydrate ($LiOH \cdot H_2O$), essential to the production of lithium base greases. (1) A **new and strategically located plant** at San Antonio, Texas (American Lithium Chemicals, Inc.). (2) **Convenient warehouse stocks** of lithium hydroxide, maintained in proximity to the major grease producing areas of the U. S. (see map). (3) **Better, faster deliveries,** because of advantageous rail and motor freight facilities. When planning your current, or future, requirements for LiOH we suggest you contact your American Potash & Chemical Corporation (Trona†) sales representative. His better service costs no more.

†TRADEMARK AP&CC

American Potash & Chemical Corporation

LOS ANGELES • NEW YORK • ATLANTA • SAN FRANCISCO • PORTLAND (ORE.)

Producers of: BORAX • POTASH • SODA ASH • SALT CAKE • LITHIUM CHEMICALS • BROMINE CHEMICALS • CHLORATES • PERCHLORATES • MANGANESE DIOXIDE *and a diversified line of specialized agricultural and refrigerant chemicals.*

Plants: TRONA and LOS ANGELES, CALIFORNIA
HENDERSON, NEVADA
SAN ANTONIO, TEXAS (American Lithium Chemicals, Inc.)
Export Div.: 99 PARK AVENUE, NEW YORK 16, NEW YORK

Engineering Societies Personnel Service

The following items are furnished by the Engineering Societies Personnel Service, Inc., a non-profit, self-supporting personnel service sponsored by ASLE, AIEE, AIME, ASCE, ASME, SNAME, ESD, ECSF, ISPE, and WSE. Replies should be addressed to the nearest office.

All positions and applicants clearing through the Chicago and Detroit Offices are 100% EMPLOYER PAYS FEES. All others are subject to negotiation and may be applicant pays fees. In all cases our fees are moderate and based on what is needed to support this non-profit service (rates available on request).

Members of the societies shown above may publish a free advertisement on this page by registering or listing at the nearest ESPS office. A weekly bulletin of Positions Open is available by subscription (rates on request).

DID YOU KNOW?

Did you know we have more than 2,000 job opportunities listed with us all of the time?

Did you know we are the only recognized Service in the professional field, recognized by practically every professional society in the country as the National Clearing house?

Did you know many employers prefer to work with us on account of our Societies' connection?

Did you know we claim to have the most qualified list of applicants in the country because of their society memberships?

Did you know we serve members and non-members with equal sincerity?

POSITIONS AVAILABLE

C-5367, Analytical Chem. BS Chem. up; age up to 35; 4-5 yrs. exp. will make non-routine analysis & method dev. on ores, refractories, slags, limes, etc.; with some knowl. of instrumentation meth. for res. lab.; car des.; for a producer of lime & cement; sal. to $7,200 plus moving exp.; loc. W. Va.; empl. will pay the fee.

C-5376, Rubber Res. & Dev. Man or woman doctorate in Chem. or equiv.; exp. 5 plus yrs. in rubber research; duties: studying the nature of rubber & metal interfaces & relating the chem. & structure of rubber to its dynamic properties, particularly vibration absorption & tension; for a res. indust.; sal. $8,500-10,500 yr.; loc. Ohio; empl. will pay the fee.

C-5428, Synthetic Organic Chem. 1 plus yrs. in synthesis of polypeptides; duties: undertake a problem using synthesis in basic res.; will get publication rights; for a med. school; sal. up to $400/mo.; loc. Chgo.; empl. will pay the fee.

C-5468, Lubrication Engr. BS in Engrg.; age 21-35; know fuels & lubricants application; (will train) duties: recommending industrial lubricants for all types of mach'y., as: turbine, hydraulic, refrig., machine shop, aviation, construction & mining, foundry steel, paper & textile mills; customer relations, lubricant specifications & field complaints sup. by engr.; trav.; car req'd.; for a refinery; sal. $5,100-8,000; loc. Okla.; empl. will pay the fee.

C-5556, Chief Engr. ME; age 40-46; 5 plus yrs. in top flight engrg. administration in internal combustion engines; know engine dev.; duties: heading up entire engrg. activities incl. dev., des., testing & prod. of 2-cycle engines for a mfr. of engines; sal. $25-30,000 plus; loc. Calif.; empl. will pay the fee.

ENGINEERS AVAILABLE

(581-LE) Domestic, Foreign Engrg. or Sales. 34; Lic. CE; 10 yrs. of sound diversified engrg.; supervisory & sales background includes good working knowledge of construction methods, machines, sales engrg. & promotion; $9,000; U.S.-Foreign.

(582-LE) Manager or Engineer. 43; BSME; 17 yrs. well-rounded exp. in management, sales & engrg.; enthusiastic, energetic, liking for responsibility; $12,000; U.S.

(583-LE) Contract or Sales Engr. (htg. vent. air cond.) 27; BSME; 2 yrs. contract engr. & estimator for mech. contractor; 2 yrs. sales engr. for mfgr.; $7,200 plus; Midwest.

(584-LE) Architect. 35; BS Arch.; 10 yrs. exp. in commercial & institutional construction & des.; $8-9,000.

(585-LE) Mech. Engr. (home appl.) 34; BSME; dev. engr. on air conditioners, window & central systems; also refrigerators & freezers; total 4½ yrs.; familiar with switches, contactors, elec. hookup 115 v & 230 v, single & 3-phase, elec. motors, compressors; $7,000; Chgo. area.

(586-LE) Dev. or Des. (el. motors-transformers) 49; BSEE; inspection & test exp., teaching & instruction exp., mech. & elect. dev. rocket launchers, fractional motors des.; $6,000; Chgo.

(587-LE) Plant Engr. or Sup't. of Maint. (textile, woodworking, machine tools, steel mills) 55; Col.; heavy background elect. & mech. engrg.; exp. to offer, maint. & construction; am considered a capable administrator with the ability to get along with people & to accomplish my objectives; $10,000 plus; South or Far West.

(588-LE) Writer. 38; Ph.D. in English; some exp. in aviation; wide range of publications; wishes job as tech. writer, editor; $7,000; East-West.

(589-LE) Safety Engr. (chem. or elect. utility) 43; MA; Safety educ. 12 yrs. indust. safety engr. & director in basic chem. electrical utility, diverse ind. with ins. adjusting agency as safety engr.; 2 yrs. exp. in personnel; $7,000; Midwest, West, South.

(590-LE) Admin. or Prod. Ass't. (mining, mineral or gen.) 49; BS mining: gen. construction, des., engrg., maint., operaiton of mines, plants & gen. knowl. of rock processing; consulting work; geological studies, reports; $9-10,000.

(591-LE) Plant or Prod. Mgr. or Ass't. (metal working mfr.) 32; ME: top notch exp. in factory mfr. & mgmt.; 6 yrs. solid resp. & supv. in lrge. precision machinery bldrs. plant; $9,000; U.S. or Foreign.

(592-LE) Sr. Engr. (petroleum) 47; BSEE; exp. circuit analysis, A.C. power circuits & relays; mech. knowl. steam power plant eqpt., piping instruments, thermodynamics, electro-mech. eqpt.; knowl. pet. process work; $10.-000; Texas.

(593-LE) Chief Bridge Engr. 55; MS: 13 yrs. as des. with a state highway dept., 10 yrs. of this time as chief bridge des. in charge of all des.; 11 yrs. in des. & supv. of various engrg. works; $8,400; West, Central or South.

(594-LE) Timestudy Engr. or Ass't. Ind. Engr. (small mfg. mach. shop) 35; approx. 5 yrs. exp. in timestudy; about 3 yrs. in estimating in light metal working & 16 mos. exp. in motion & timestudies on punch presses & welders; 1 yr. ass't. ind. engr.; $6,000; Chgo.

(595-LE) Ass't. Factory Mgr., Prod. Sup't. or Ind. Engr. 29; BSIE; sr. IE; 5 yrs. exp. multi-plant metal fabricating co. in job eval. wage & salary admin., wage incentives, time & motion, methods, plant layout, collective bargaining, grievances, arbitration; $9,000; Chgo. area.

(597-LE) Ind. Engr. 33; 4 yrs. col.; chief ind. engr. for small plant resp. for methods dev., set incentive rates, plant layout, material & labor specs., also safety dir. of same; $7,200; Chgo. area.

Remember . . .

All positions and applicants clearing through the Chicago & Detroit Offices are . . .

100%

EMPLOYER PAYS FEES

ASLE Publications
ORDER BLANK

Fundamentals Of Friction & Lubrication In Engineering

Proceedings of 1st ASLE National Symposium: Historical Development of Hydrodynamic Lubrication; Remarks on Mixed Film Lubrication; Lubrication Concepts & Engineering Application; Hydrodynamically Lubricated Roll Neck Bearings; Fundamentals of Hydrodynamic Lubrication; Vertical Pivoted Shoe Thrust Bearings; On the Need for a Non-Steady State Theory for Lubrication Hydrodynamics; Lubrication of Gear Teeth, Including the Effect of Elastic Displacement; Physics & Chemistry of Rubbing Solids—Basic Principles; On the Friction & Wear of Graphite & Other Layer-Latticed Solids; The Importance of Wear Fragments During Sliding; Technical Applications of Principles of Solid Sliding Contact. $3.00 per copy to members, $3.50 per copy to non-members.

Interpreting Service Damage In Rolling Type Bearings

A manual on ball and roller bearing damage which includes drawings, tables, and 74 photographs for aiding in the classification and identification of the causes of many of the common types of bearing damage. $1.00 per copy.

"Lubrication Engineering" Decennial Index

Subject & Author Indexes listing the papers published in **Lubrication Engineering**, Journal of the American Society of Lubrication Engineers, in Volumes 1 thru 10 (1945 thru 1954). 50c per copy.

Petroleum-Type Hydraulic Fluids

Second in the series of ASLE monographs, covering Hydraulic Oil Specifications & Service Properties, Viscosity, Viscosity Index, Demulsibility, Oxidation Stability, Lubricating Value, Rust & Corrosion Preventive Qualities. $1.00 per copy.

Physical Properties Of Lubricants

First in the series of ASLE monographs, covering Viscosity, Density & Specific Gravity, Cloud & Pour Points, Flash & Fire Points, Carbon Residue, Neutralization Number & Interfacial Tension, Saponification Number, Emulsification, Specific Heat. $1.00 per copy.

Practical Lubrication, Vol. 1

Ten practical articles giving information fundamental to the carrying out of successful lubrication practices in industry: Cleaning Lubrication Systems, Coal Mine Lubrication, Grease Lubrication of Ball Bearings, Lubricating Grease, Lubrication Requirements of Gears as Seen by a Gear Engineer, Open Gear Lubrication, Planned Lubrication as a Part of Plant Maintenance, Reduction of Gear Failures, Seals & Closures, Steel Mill Lubrication from Management's Point of View. $1.00 per copy.

Indicate opposite title the number of copies desired, fill in your name and address, enclose remittance, and mail to:
ASLE, 84 E. Randolph St., Chicago 1, Ill.

Name .....

Address .....

.....
(Please Print)

Advertisers' Index

Acheson Colloids Co. 290
Alemite Div., Stewart-Warner Corp. 294
Alpha Molykote Corp., The 304
American Potash & Chemical Corp. 350
Atlantic Refining Co., The 296
Baroid Div., National Lead Co. 344
Brooks Oil Co., The 302
Burns Laboratories, Inc. 348
Carbide & Carbon Chemicals Co. 349
Climax Molybdenum Co. 339
Commercial Filters Corp. 345
Farval Corp., The ..... (Inside Back Cover)
Grafo Colloids Corp. 352
Hodson Corp., The ..... (Back Cover)
Houghton & Co., E. F. 300
Lincoln Engineering Co., Div. of The McNeil Machine & Engineering Co. ..... 340 & 341
Madison-Kipp Corp. 346
Manzel Div. of Houdaille Industries, Inc. 338
Morgan Construction Co. 292
Norgren Co., C. A. 337
Rothlan Corp. ..... 342 & 347
Shell Oil Co. 298
Sinclair Refining Co. 343
Sun Oil Co. ..... 336A & B
Trabon Engineering Corp. ..... (Inside Front Cover)

Classified 344

GRAFO Colloidal Dispersions

Give You So Much More
In Hot Forging Operations

- Better Working Conditions
- Better Metal Flow
- Reduced Die Wear
- Much Closer Tolerances
- Freedom from Sticking and Galling
- Better Finished Products
- Increased Production

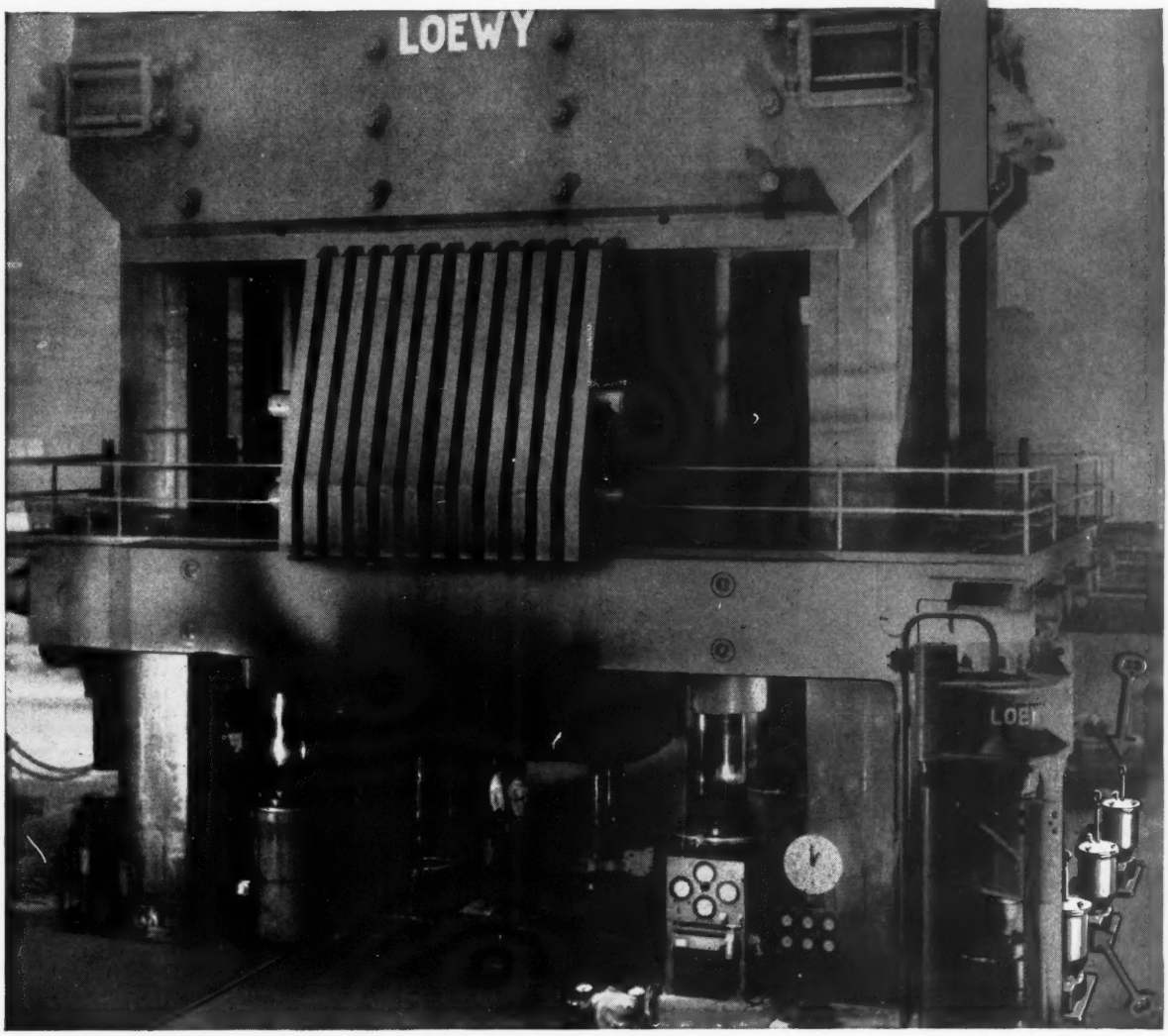
***There Is* A Grafo Lubricant To Do Your Specific Job Better For Less**

Write Us Regarding Your Special Problem

Grafo COLLOIDS CORPORATION
269 WILKES PLACE
SHARON, PENNSYLVANIA

Loewy 50,000-ton "Major" forging press is automatically lubricated by Farval

FARVAL—
Studies in Centralized Lubrication
No. 196



It takes only one man at the control pulpit to operate this huge 11-story press—the world's largest machine. Designed and built by Loewy-Hydropress Div. Baldwin-Lima-Hamilton of New York for the U.S.A.F. Heavy Press Program and operated by the Wyman-Gordon Co., it can exert 108 million pounds' pressure to form hot aluminum billets into structural parts for jet planes.

Adequate lubrication—and always dependable—helps this machine work to greater precision tolerances than ever before thought possible in a forging press. Lubrication is by Farval—a total of 205 bearings served by four systems—three heavy-duty automatics for the lubrication of the press proper and one manual for the lubrication of the controls.

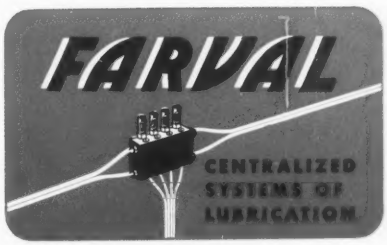
Farval Centralized Lubrication Systems are serving millions of bearings in all kinds of industrial equipment. Farval is ready to serve you, too. Call the Farval representative near you, or write us for Bulletin 26-R. The Farval Corporation, 3267 East 80th St., Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

KEYS TO ADEQUATE LUBRICATION—

Wherever you see a Farval central pumping station, dual lubricant lines, and valve manifolds, you know a machine is being properly lubricated.

Three Farval heavy-duty automatic pumping stations that lubricate "Major" are to be seen at lower right.



HODSON

THIXOTROPIC LUBRICANTS

*

DENSOIL is an extreme pressure, fibrous structure, paraffin base oil lubricant, so versatile as to be used in small gears and bearings as well as heavy-duty mill equipment where extreme conditions exist.

DENSOIL can be used advantageously for all types of enclosed geared units, both for teeth and bearings — sleeve and anti-friction, from the heaviest type of industrial equipment to that used in household utilities, such as washing machines, etc.

DENSOIL Lubricant is temperature resistant. It has cushioning and shock absorbing characteristics plus excellent adhesion and cohesion at high peripherals which prevents metal grab and consequent scoring and cutting.

DENSOIL builds up a lacquer-like, tough, oily film, high in lubricity, on bearing surfaces as used in mill equipment for Pinions, Cables, Screw Downs, Couplings, Columns, Bearings, Worm Drives and Guides.

DENSOIL

• • • • •

GEARKOTE combines the qualities of both lubricant and protective shield. Formulated for the severe service of heavy equipment, including cast or roughly finished gears.

GEARKOTE is exceedingly resistant to water such as commonly found in edging roll drives, housing roll gears, table line shaft housings, and semi-open pinions.

The heavier consistencies settle in the housings under water but lubricating qualities remain unimpaired. Surplus water can be drained during shutdown periods without loss of GEARKOTE.

GEARKOTE

GEARKOTE is a registered trade mark of
The Hodson Corporation

The HODSON CORPORATION

Lubrication

5301-11 WEST SIXTY SIXTH STREET

CHICAGO 38, ILLINOIS

*Phenomenon shown by gels, namely, that of becoming liquid on stirring and resolidifying on standing.

9-10-L-56

PRINTED IN U.S.A.